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R.H. SAUNDERS GS
CONCRETE MOVEMENT INVESTIGATION

Report No. 91-91-K

G.J. Czuppon
Engineer
Concrete Technology Section
Civil Research Department

ABSTRACT

An investigation of the condition of the concrete in Unit 4 of R.H. Saunders GS was conducted in December 1990 and January 1991. The investigation consisted of documenting the extent of cracking in the water passages, obtaining concrete cores from the scroll case, draft tube, service levels and inspection tunnel, testing specimens of the concrete cores to determine the physical properties of the concrete, examining the concrete cores petrographically and installing thermocouples in the in-situ concrete to enable long-term temperature measurements. The results of the field and laboratory investigations are detailed.

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To: Dr. C.F. Lee
Manager
Civil Engineering & Architecture Department

Attn: Mr. J.H.K. Tang/Dr. A. Danay

R.H. SAUNDERS GS
CONCRETE MOVEMENT INVESTIGATION

1.0 INTRODUCTION

At the request of Dr. A. Danay of the Civil Engineering and Architecture Department, an investigation of the condition of the concrete in Unit 4 of R.H. Saunders GS was conducted by the Concrete Technology Section, Civil Research Department, in December 1990 and January 1991.

The investigation is part of a study undertaken by the Civil Engineering and Architecture Department to determine the causes of concrete movement at R.H. Saunders GS.

The purpose of the investigation carried out by the Concrete Technology Section was to document the extent cracking in the water passages, obtain concrete cores from selected areas along cracks and construction joints, test the concrete cores for the physical properties of the concrete, examine the concrete cores petrographically and install thermocouples in the in-situ concrete to enable long-term temperature measurements.

This report summarizes the results of the investigation.

2.0 SCOPE OF INVESTIGATION

The investigation consisted of the following stages:

1. Mapping of cracks in selected areas in the scroll case and draft tube of Unit 4 to document the width and spacing of these cracks.
2. Obtaining concrete cores along the crack paths to measure the width of the crack with respect to depth and determine the penetration depth of calcium carbonate deposits.
3. Obtaining concrete cores from selected areas to determine the physical properties of the concrete.
4. Obtaining concrete cores on selected construction joints to determine the bond condition of the joints.
5. Testing of cores taken from open construction joints to determine the coefficient of friction of the joints.
6. Petrographic examination of concrete cores and microscopic examination of thin sections prepared from concrete cores taken from selected locations.
7. Installing 42 thermocouples at 21 locations in the in-situ concrete to enable long-term temperature measurements.

3.0 RESULTS

3.1 Crack Mapping - Scroll Case/Draft Tube

The crack mapping areas in the scroll case and the draft tube are identified in Figures 1 and 2, respectively. The crack mappings for each area are shown in Figures 3 to 14. The crack widths and the locations of cores (100 mm diameter) drilled within the mapping areas are shown in each figure. A concrete core log is given in Appendix A.

Concrete cores taken from within the mapping areas were cut longitudinally, perpendicular to the crack, thus exposing the crack. One half of each core was polished to assist in the evaluation of the crack width. The width of the crack with respect to depth and the depth of penetration of calcium carbonate for the selected cores are given in Tables 1 to 7. Photographs of these cores are given in Appendix B.

3.2 Physical Properties of the Concrete

Concrete cores (100 mm diameter) were selected for testing to determine the physical properties of the concrete. The results of the compressive strength (CAN-A23.2-14C), density, and absorption (ASTM C 642) tests are given in Table 8. Except for the absorption tests, the specimens were saturated in water at 23°C for 48 hours before testing. For the absorption tests, the specimens were saturated at 23°C for 24 hours before testing. The size of all core specimens tested for compressive strength met CSA Standard CAN-A23.2-14C. This standard specifies that the core length be at least twice the core diameter and the core diameter be at least three times the nominal maximum aggregate size.

3.3 Bond Condition of Construction Joints

Concrete cores (100 mm diameter) were drilled on selected construction joints to determine the bond condition of the joint. The identification of each joint along with its corresponding bond condition is shown in Tables 9 to 11. The concrete core log is given in Appendix A.

3.4 Shear Friction and Shear Strength of Construction Joints

Concrete cores taken from open construction joints were tested for shear friction along the plane of the joint. These samples were tested using a portable shear box. The results of these tests are given in Table 12.

3.5 Petrographic Examination of Concrete Cores

Nine concrete cores were selected for examination. Also, nine large thin sections (40 x 70 mm) were prepared for microscopic examination. The results of the petrographic examination are given in Research Division Report No. S91-15-K.

3.6 Installation of Thermocouples

Thirty-five mm diameter holes were cored in 21 locations and 42 thermocouples were installed. The locations and placement depths of the thermocouples are given in Table 13.

4.0 SUMMARY

Crack widths were less than 0.5 mm, with most crack widths reduced to less than 0.1 mm beyond depths of 100 mm. Most cracks lacked any mineralization, such as calcium carbonate. Some of the cores from the draft tube and the east wall of the scroll case did contain calcium carbonate linings along cracks. However, this infilling of cracks was limited to the top 100 mm of the cores.

The density of the concrete ranged from 2323 to 2601 kg/m^3, with an average of 2439 kg/m^3. The absorption of the concrete ranged from 4.0% to 6.8%, with an average of 5.6%. The compressive strength of the concrete ranged from 44.5 to 60 MPa, with an average of 47.8 MPa.

The average coefficient of friction of the construction joint was 0.25 measured at a normal load of 30 kN.

5.0 ACKNOWLEDGEMENTS

Mr. D.A. McKay of the Rock Sciences Section, Civil Research Department and Mr. E.M. Dobrowolski of R.H. Saunders GS are acknowledged for their assistance in the investigation.

Approved by:

J.B. Brown
Manager
Civil Research Department

Prepared by:

G Czuppon

G.J. Czuppon
Engineer
Concrete Technology Section

Reviewed by:

G.S. Kellay
Supervising Engineer
Concrete Technology Section

GJC:ttd

TABLE 1

R.H. SAUNDERS G.S.
UNIT 4 SCROLL CASE
WEST BAY, WEST WALL – CMITWW1
Crack Mapping of Concrete Cores

Core No.	Crack Depth (mm)	Crack Width (mm)	Mineralization	Commenty
CCITWW13 to CCITWW17				Core sections were not polished. Cracks visible at surface only.
CCITWW18 Figure B3	0–40 40–120	<0.1 <<0.1		Numerous, randomly orientated cracks.

TABLE 2

R.H. SAUNDERS G.S.
UNIT 4 SCROLL CASE
WEST PIER – CMITWP2
Crack Mapping of Concrete Cores

Core No.	Crack Depth (mm)	Crack Width (mm)	Mineralization	Comments
CCITWP19	5	2.0		
Figure B4	10	1.0		
	20	0.2		
	40	0.3		
	60	0.2		
	80	0.1		
	95–135	<0.1		End of core.
CCITWP20	5	2.0		
Figure B4	20	0.1		
	40	0.6		
	60	<0.1		
	80	0.3		
	100–135	<0.1		End of core.
CCITWP21	0	<0.1		Three cracks at surface only.
Figure B4	20	0.2		Single crack
	40	0.1		
	60	0.1		
	60–110	<0.1		Single crack divides into two cracks.
CCITWP22 and CCITWP23				Core sections were not polished. Cracks visible at surface only.

TABLE 3

R.H. SAUNDERS G.S.
UNIT 4 SCROLL CASE
EAST PIER – CMITEP3
Crack Mapping of Concrete Cores

Core No.	Crack Depth (mm)	Crack Width (mm)	Mineralization	Comments
CCITEP24	0	6.0		
Figure B4	20	0.8		
	40	0.1		
	60	0.3		
	80	0.4		
	100	0.2		End of crack.
	130	-		End of core.
CCITEP25	0–40	0.1		
Figure B5	40	<0.1		
	60	0.3		
	60–105	<0.1		
	105–180	<<0.1		
CCITEP26	0	0.2		
Figure B5	20–40	<0.1		Series of subparallel, horizontal cracks.
	40–145	<0.1		End of crack.
	145–165	-		End of core.

TABLE 4

R.H. SAUNDERS G.S.
UNIT 4 SCROLL CASE
EAST BAY, WEST WALL – CMITEP4
Crack Mapping of Concrete Cores

Core No.	Crack Depth (mm)	Crack Width (mm)	Mineralization	Comments
CCITEP10	0–105	<0.1		–
Figure B3	105–155	<<0.1		Several, randomly orientated fine cracks.
	155	–		End of core.
CCITEP11	0–20	1.0		
Figure B3	20–135	<0.1		End of core/corroded rebar at 135 mm.
CCITEP12				Two cracks present in plane.
Figure B3	0	0.1		Top crack.
	20	0.3		
	40	0.5		
	60	0.1		
	80	0.3		
	100	–		End of core.
	0–10	<0.1		Bottom crack.
	20–60	0.1		
	60–80	<0.1		
	100	–		End of core.
CCITEP27	0–45	<0.1		
Figure B5	45–65	–		No crack.
	65–125	<0.1		End of core.
CCITEP29	0	0.3		
Figure B6	20	0.2		
	40	0.4		
	60	0.1		
	80	<0.1		Single crack divides into two cracks.
	100	0.1		End of core.

TABLE 5

R.H. SAUNDERS G.S.
UNIT 4 SCROLL CASE
EAST BAY, EAST WALL – CMITEW5
Crack Mapping of Concrete Cores

Core No.	Crack Depth (mm)	Crack Width (mm)	Mineralization	Comments
CCITEW6	0–20	0.2	Calcium carbonate	
Figure B2	40	0.2		
	60	0.1		
	75–170	<0.1		End of core.
CCITEW7	5–110	<0.1		
Figure B2	125			End of core.
CCITEW8	5–40	0.2		
Figure B2	40–100	<0.1		
	130			End of core.
CCITEW9	10	<0.1		Single crack
Figure B2	40	<0.1		Two separate cracks.
	50	<0.1		Single crack
	60	<0.1		Two separate cracks.
	100	<0.1		
	100–140	<<0.1		Numerous, randomly orientated fine cracks.
				End of core.
CCITEW28	0	0.2		
Figure B5	20–40	0.1		
	60	0.2		
	80	0.1		
	100	0.3		
	120	0.1		
	120–130	-		No crack. End of core.

TABLE 6

R.H. SAUNDERS G.S.
UNIT 4 SCROLL CASE
EAST WALL – CMSCEW6
Crack Mapping of Concrete Cores

Core No.	Crack Depth (mm)	Crack Width (mm)	Mineralization	Comments
CCSCEW2	0–20	0.3	Calcium carbonate	
Figure B1	20–40	0.4	Calcium carbonate	
	40–60	0.2	Calcium carbonate	
	60–80	0.1	Calcium carbonate	
	80–170	<0.1		End of core.
CCSCEW3	0	0.2		
Figure B1	20–30	0.3	Calcium carbonate	
	40	0.2		
	60	0.2		
	70–80	0.1	Calcium carbonate	
	100–150	0.1		End of core/uncorroded rebar at 150 mm.
CCSCEW4	0–40	<0.1	Calcium carbonate	
Figure B1	40–50	-		No crack.
	50–100	<0.1		
	100–135	-		No crack. End of core.
CCSCEW5	0–40	0.1	Calcium carbonate	
Figure B1	40–125	<0.1		End of core/uncorroded rebar at 125 mm.

TABLE 7

R.H. SAUNDERS G.S.
UNIT 4 DRAFT TUBE
Crack Mapping of Concrete Cores

Core No.	Crack Depth (mm)	Crack Width (mm)	Mineralization	Comments
CCDTEW1	0	3.0	Calcium carbonate	
	5	0.6	Calcium carbonate	
	20	0.5	Calcium carbonate	
	40	0.6	Calcium carbonate	
	60	0.5	Calcium carbonate	
	80	0.4	Calcium carbonate	
	100	0.2	Calcium carbonate	
	100–160	<0.1		End of core.
CCDTEP2	0–40	<0.1		End of crack.
	270			End of core/uncorroded re-bar at 270 mm.
CCDTEP3	0–80	0.1	Calcium carbonate	
	80–110	0.1		
	110–130	—		No crack. End of core.
CCDTWP4	0–60	<0.1		End of crack.
	250			End of core. Core section was not polished.
CCDTWP5	0–15	<0.1	Calcium carbonate	
	15–50	<0.1		End of crack.
	270			End of core/uncorroded rebar at 270 mm.
				Core section was not polished.

TABLE 8

R.H. SAUNDERS G.S.
Concrete Properties

Core	Compressive Strength (MPa)	Density (kg/m3)	Absorption (%)
SCROLL CASE			
CCSCEW1	24.2	2378	
JCSCWW4-3		2438	5.5
JCSCWW4-3		2384	6.8
JCSCWW5-4		2415	6.0
JCSCWW5-4		2452	4.8
CSCSW1-3	44.5	2459	
JCSCSW6-1		2387	6.3
JCSCSW6-3		2435	5.6
JCSCEW1-4		2413	5.5
JCSCEW2-1		2393	6.5
DRAFT TUBE			
CDTEW1		2486	4.0
CDTEW2		2394	5.9
CDTEW3		2601	5.4
CDTEW4	46.3	2502	
CDTEW5	45.5	2450	
INSPECTION TUNNEL			
JCIG8-6		2452	5.3
JCIG8-6		2477	4.4
CCIG9	44.5	2482	
S4 LEVEL			
CC6S7		2323	6.0
JC66S5-2		2455	4.7
JC66S5-3	58.1	2510	
S2 LEVEL			
CC66S6		2373	6.3

TABLE 9

R.H. SAUNDERS G.S.
Scroll Case
Bond Condition of Construction Joints

Core	from-to (mm)	
JCSCEW1	East Wall @ nose of pier - 2670 mm from floor	
1-1	0-210	Closed
1-2	210-390	Closed
1-3	390-640	Open
1-4	640-1000	Closed
1-5	1000-1190	Key
1-6	1190-1300	Key
1-7	1300-1500	Closed
JCSCEW2	East Wall @ nose of pier - 2060 mm from floor	
2-1	0-230	Closed
2-2	230-410	Closed
2-3	410-650	Closed
2-4	650-800	Closed
2-5	800-1000	Open
2-6	1000-1332	Key
JCSCEW3	East Wall @ nose of pier - 4650 mm from floor	
3-1	0-230	Closed
3-2	230-330	Open
3-3	330-450	Open
3-4	450-660	Open
3-5	660-920	Closed
3-6	920-1000	Open
3-7	1000-1160	Key
3-8	1160-1330	Key
JCSCWW4	West Wall - 1680 mm from floor	
4-1	0-190	Open
4-2	190-380	Open
4-3	380-620	Open
4-4	620-840	Open
4-5	840-1000	Open
4-6	1000-1335	Key

TABLE 9 continued

R.H. SAUNDERS G.S.
Scroll Case
Bond Condition of Construction Joints

Core	from-to (mm)	
JCSCWW5	West Wall - 1750 mm from floor	
5-1	0-170	Closed
5-2	170-370	Closed
5-3	370-600	Closed
5-4	600-840	Open
5-5	840-970	Open
5-6	970-1220	Key
JCSCSW6	Downstream Wall - 3835 mm from floor	
6-1	0-230	Closed
6-2	230-370	Closed
6-3	370-600	Closed
JCSCSW7	Downstream Wall - 3960 mm from floor	
7-1	0-160	Closed
7-2	160-430	Closed
7-3	430-620	Closed
7-4	620-870	Closed

TABLE 10

R.H. SAUNDERS G.S.
Draft Tube
Bond Condition of Contsruction Joints

Core	from-to (mm)	
JCDTEW8	East Bay:East Wall - Horizontal - 3400 mm from floor	
8-1	0-130	Open
8-2	130-300	Open
8-3	300-580	Closed
8-4	580-720	Closed
8-5	720-980	Closed
JCDTEW9	East Bay:East Wall - Vertical - 3785 mm from floor	
9-1	0-130	Open
9-2	130-360	Closed
9-3	360-630	Closed
JCDTEP10	East Bay:West Wall - Vertical - 3660 mm from floor	
10-1	0-200	Open
10-2	200-430	Open
10-3	430-660	Open
JCDTEP11	Middle Bay:East Wall - Vertical - 4775 mm from floor	
11-1	0-190	Open
11-2	190-520	Closed
11-3	520-800	Closed
JCDTEP12	Middle Bay:East Wall - Horizontal - 4650 mm from floor	
12-1	0-250	Closed
12-2	250-500	Closed
12-3	500-770	Closed

TABLE 11

R.H. SAUNDERS G.S.
Dry Areas
Bond Condition of Contsruction Joints

Core	from-to (mm)		
	S2 LEVEL		
JC66S4	Upstream Wall - Horizontal Joint		
-1	0-320	Open	
	no core samples retained.		
	joint open 320 mm into hole.		
JC66S9	Upstream Wall - Vertical Contraction Joint		
	Joint between G3&G4		
-1	0-270	Closed	
-2	270-490	Closed	(open in transport)
-3	490-650	Closed	
-4	650-980	Closed	
-5	980-1300	Closed	
-6	1300-1665	Closed	
	S4 LEVEL		
JC66S5	Downstream Wall - Horizontal Joint		
-1	0-260	Closed	(crack to 120 mm depth)
-2	260-550	Closed	
-3	550-820	Closed	
	INSPECTION TUNNEL		
JCIG8	Downstream Wall - Vertical Contraction Joint		
	Joint between G4&G5		
-1	0-100	Closed	
-2	100-220	Closed	
-3	220-530	Closed	
-4	530-800	Closed	
-5	800-1070	Closed	
-6	1070-1330	Closed	
	GENERATOR ROOM		
JC44W3	West Wall - Horizontal Contraction Joint		
-1	0-160	Open	

TABLE 12

Coefficient Of Friction
Construction Joints

Core ID	Location	Static Load kN (lbf)	μs	Dynamic Load kN (lbf)	μd
JCSCEW2-3	Scroll Case	7.47 (1680)	.2486	5.48 (1230)	.1828
JCSCEW2-5	Scroll Case	6.97 (1565)	.2320	4.98 (1120)	.1657
JCSCEW3-4	Scroll Case	8.26 (1855)	.2751	6.72 (1510)	.2237
JCSCWW4-1	Scroll Case	5.87 (1320)	.1955	4.98 (1120)	.1657
JCDTEP10-1	Draft Tube	6.07 (1365)	.2022	3.98 (895)	.1325
JCDTEP10-2	Draft Tube	6.97 (1565)	.2320	4.98 (1120)	.1657
JCDTEP10-3	Draft Tube	6.72 (1510)	.2237	4.98 (1120)	.1657

Normal Load = 30 kN (6750 lbf)

Static load is force required to start movement.

Dynamic load is force required to maintain constant movement.

μs = static coefficient of friction

μd = dynamic coefficient of friction

TABLE 13

R.H. SAUNDERS G.S.
Unit 4
Thermocouple Locations and Depths

Area	Location	Label	Depth (ft)	Colour Code
EL. 256'	Upstream Deck	TCCR-1S	0	yellow
		TCCR-1D	6	red
		TCCR-2S	0	yellow
		TCCR-2D	3	red
EL. 220'	Wall	TC220-1S	0	yellow
		TC220-1D	4	red
EL. 192'	Wall	TC192-1S	0	yellow
EL. 180'	Gallery Upstream Wall	TC180-1D1	6	red
		TC180-1D2	12	white
	Gallery Floor	TC180-2S	0	yellow
		TC180-2D	6	red
	Generator Room Upstream Wall	TC180-3S	0	yellow
	Generator Room West Wall	TC180-4S	0	yellow
S1 Level	Upstream Wall	TCS1-1S	0	yellow
		TCS1-1D	6	red
S2 Level	Downstream Wall	TCS2-1S	0	yellow
		TCS2-1D1	1.5	red
		TCS2-1D2	3	white
	Upstream Wall	TCS2-2S	0	yellow
		TCS2-2D	6	red

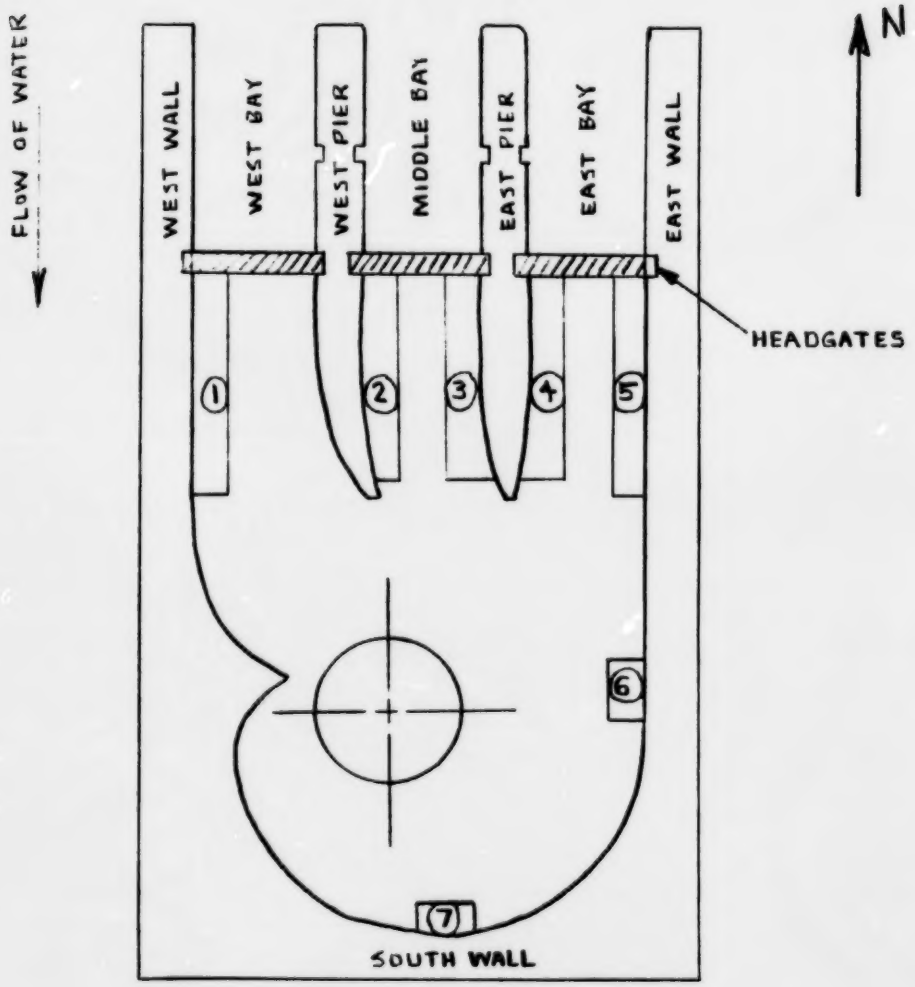
TABLE 13 continued

R.H. SAUNDERS G.S.
Unit 4
Thermocouple Locations and Depths

Area	Location	Label	Depth (ft)	Colour Code
S3 Level	Upstream Wall	TCS3-1S	0	yellow
		TCS3-1D	4	red
	Downstream (middle room)	TCS3-2S	0	yellow
		TCS3-2D1	1.5	red
		TCS3-2D2	3	white
S4 Level	Upstream Wall	TCS4-1S	0	yellow
		TCS4-1D1	6	red
		TCS4-1D2	12	white
	Gallery Floor	TCS4-2D1	6	red
		TCS4-2D2	12	white
	Downstream Floor (3rd room)	TCS4-3D	6	red
	Downstream (middle room)	TCS4-4S	0	yellow
		TCS4-4D1	1.5	red
		TCS4-4D2	3	white
Inspection Tunnel	Floor (upstream)	TCIG-1D1	6	red
		TCIG-1D2	12	white
	Floor (downstream)	TCIG-2S	0	yellow
		TCIG-2D1	6	red
		TCIG-2D2	12	white
	Upstream Wall	TCIG-3D	6	red
	Downstream Wall	TCIG-4D1	6	red
		TCIG-4D2	12	white

FIGURE 1

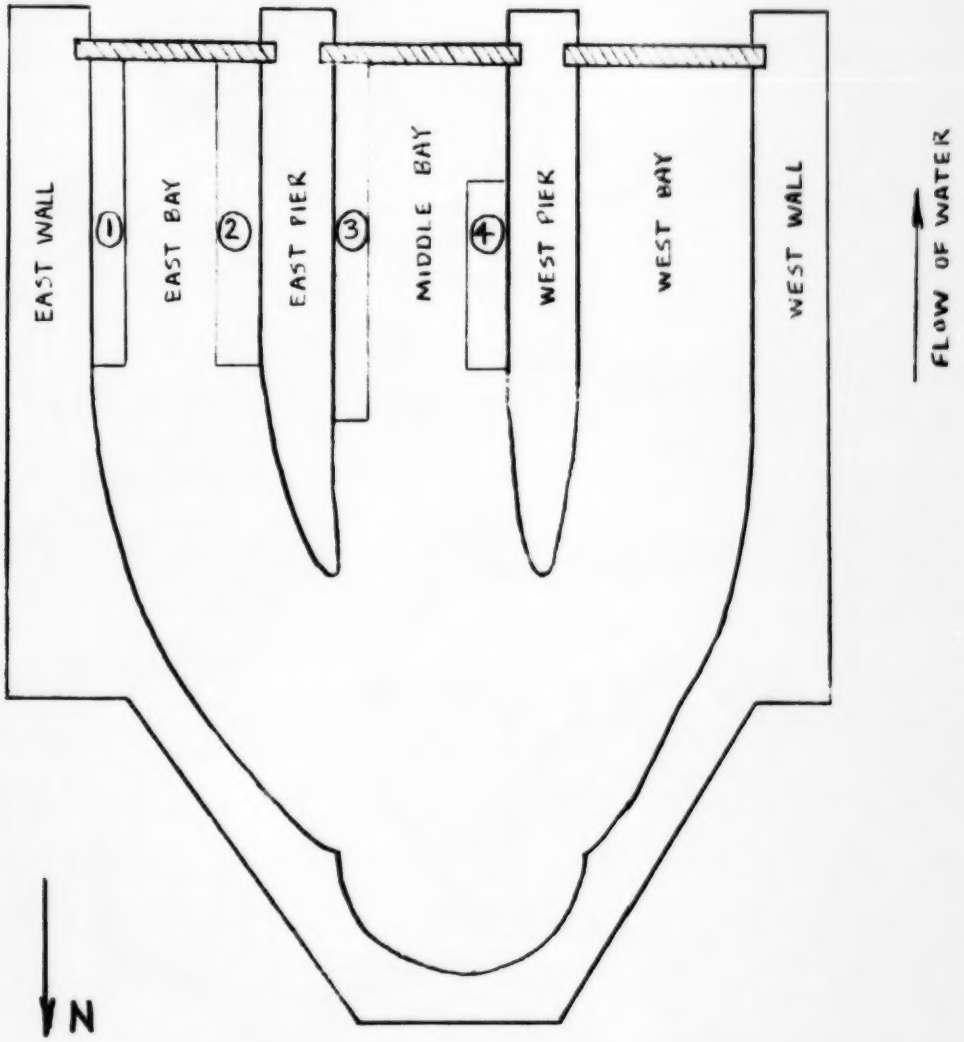
R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
Mapping Areas



1 - INTAKE WEST WALL - CMITWW1
2 - INTAKE WEST PIER - CMITWP2
3 - INTAKE EAST PIER - CMITEP3
4 - INTAKE EAST PIER - CMITEP4
5 - INTAKE EAST PIER - CMITEW5
6 - SCROLL CASE EAST WALL - CMSCEW6
7 - SCROLL CASE SOUTH WALL CMSCSW7

FIGURE 2

R.H. SAUNDERS G.S.
UNIT 4 - DRAFT TUBE
Mapping Areas



1 - DRAFT TUBE EAST WALL - CMDTEW1
2 - DRAFT TUBE EAST PIER - CMDTEP2
3 - DRAFT TUBE EAST PIER - CMDTEP3
4 - DRAFT TUBE WEST PIER - CMDTWP4

FIGURE 3

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
1 - INTAKE WEST WALL - CMITWW1
Mapping Area

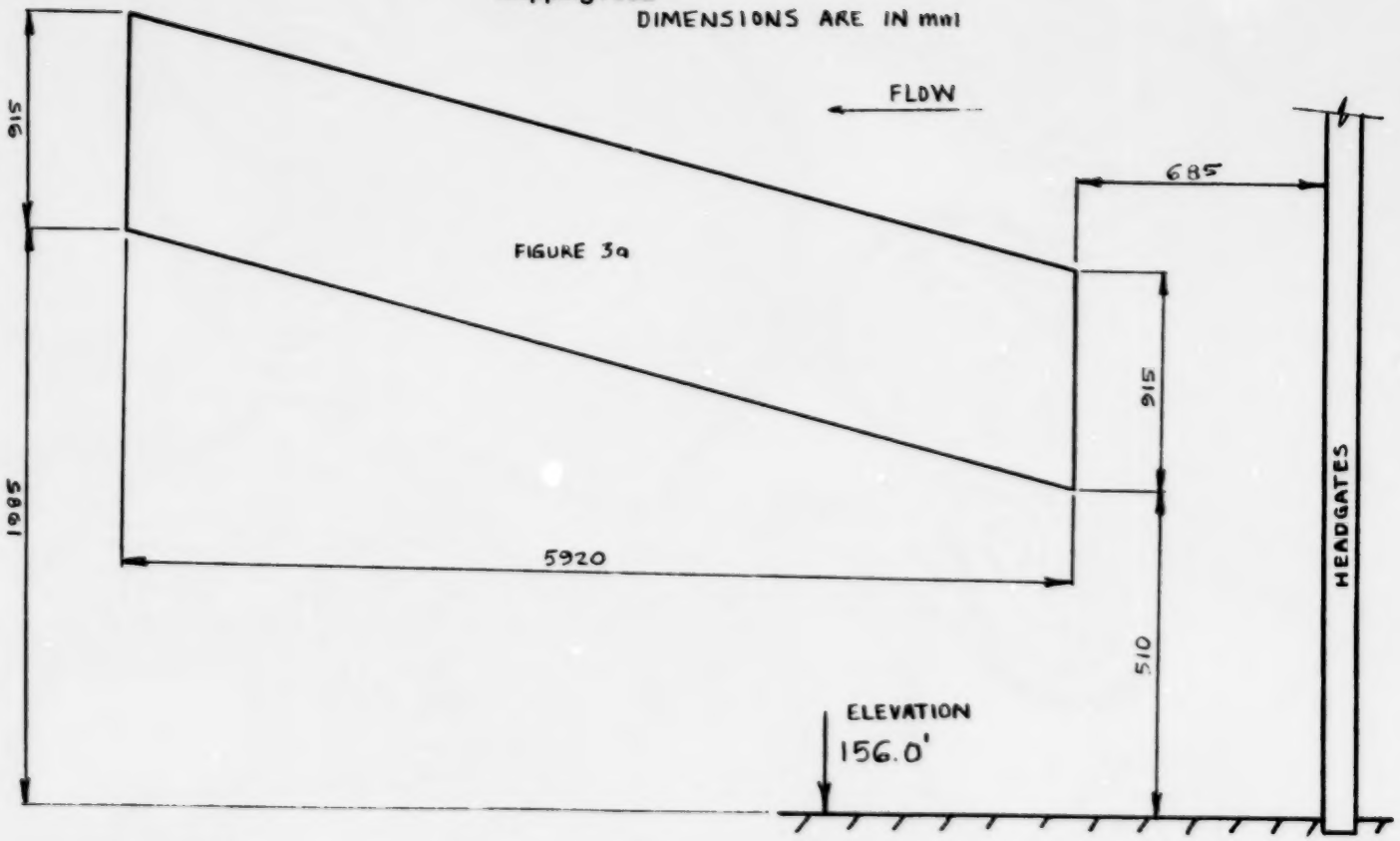
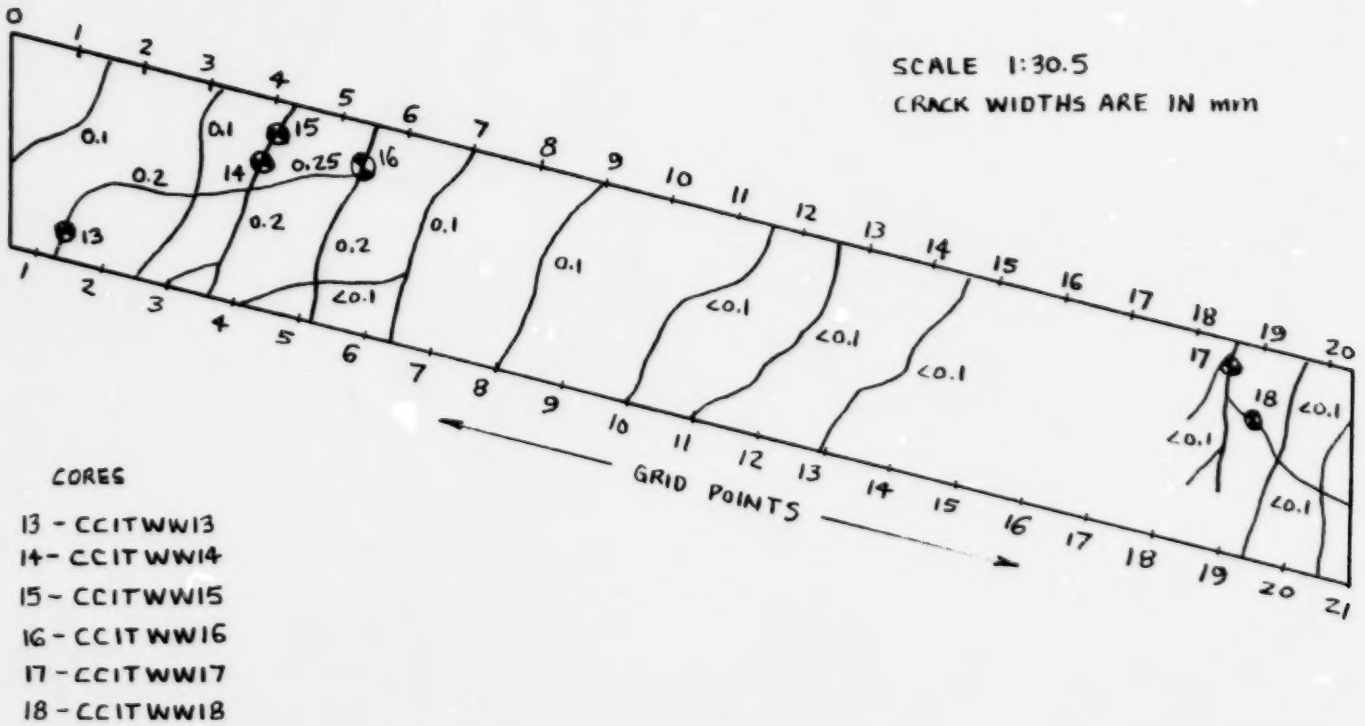


FIGURE 3a

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
1 - INTAKE WEST WALL - CMITWW1
Crcak Mapping and Core Locations



CORES

13 - CCITWW13
14 - CCITWW14
15 - CCITWW15
16 - CCITWW16
17 - CCITWW17
18 - CCITWW18

FIGURE 4

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
2 - INTAKE MIDDLE BAY WEST PIER - CMITWP2
Mapping Area

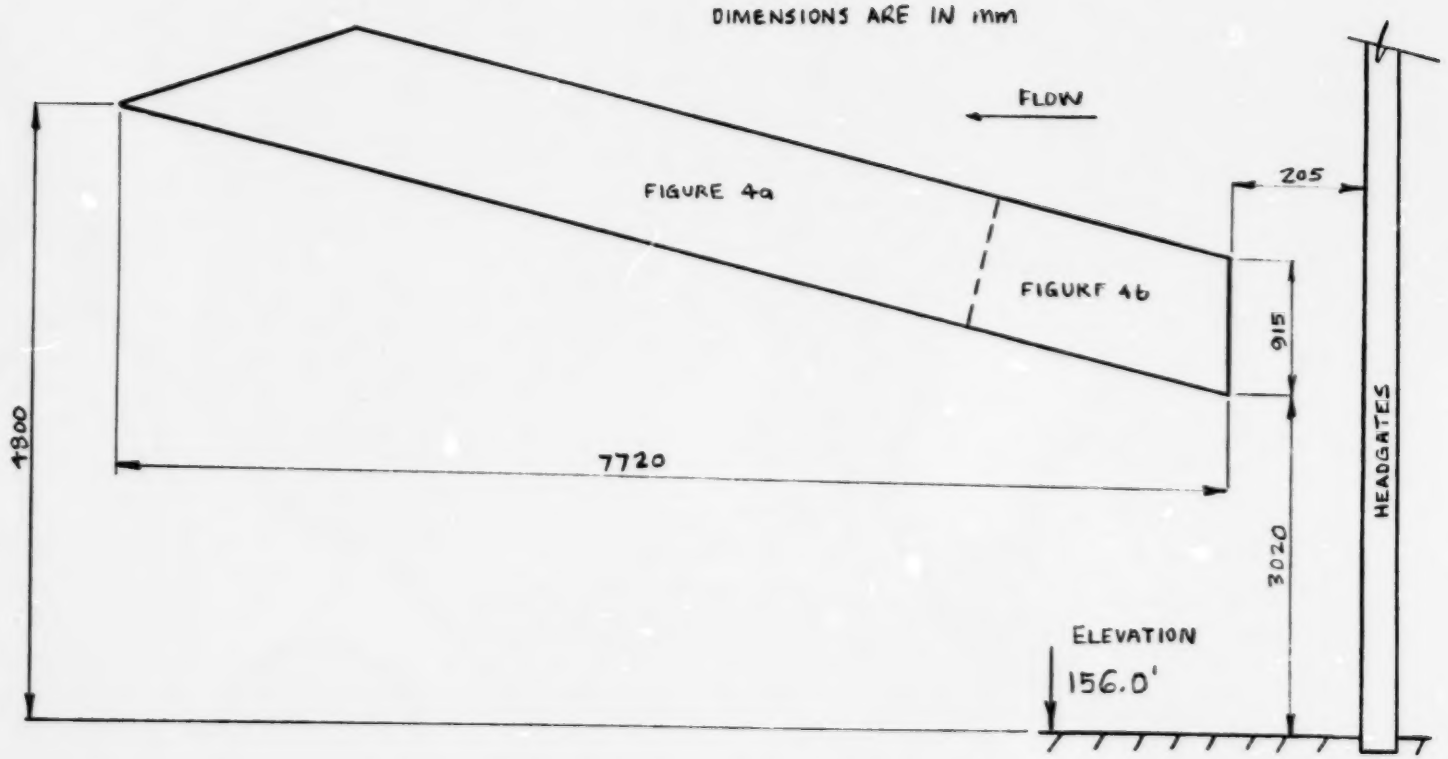


FIGURE 4a

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
2 - INTAKE MIDDLE BAY WEST PIER - CMITWP2
Crack Mapping and Core Locations

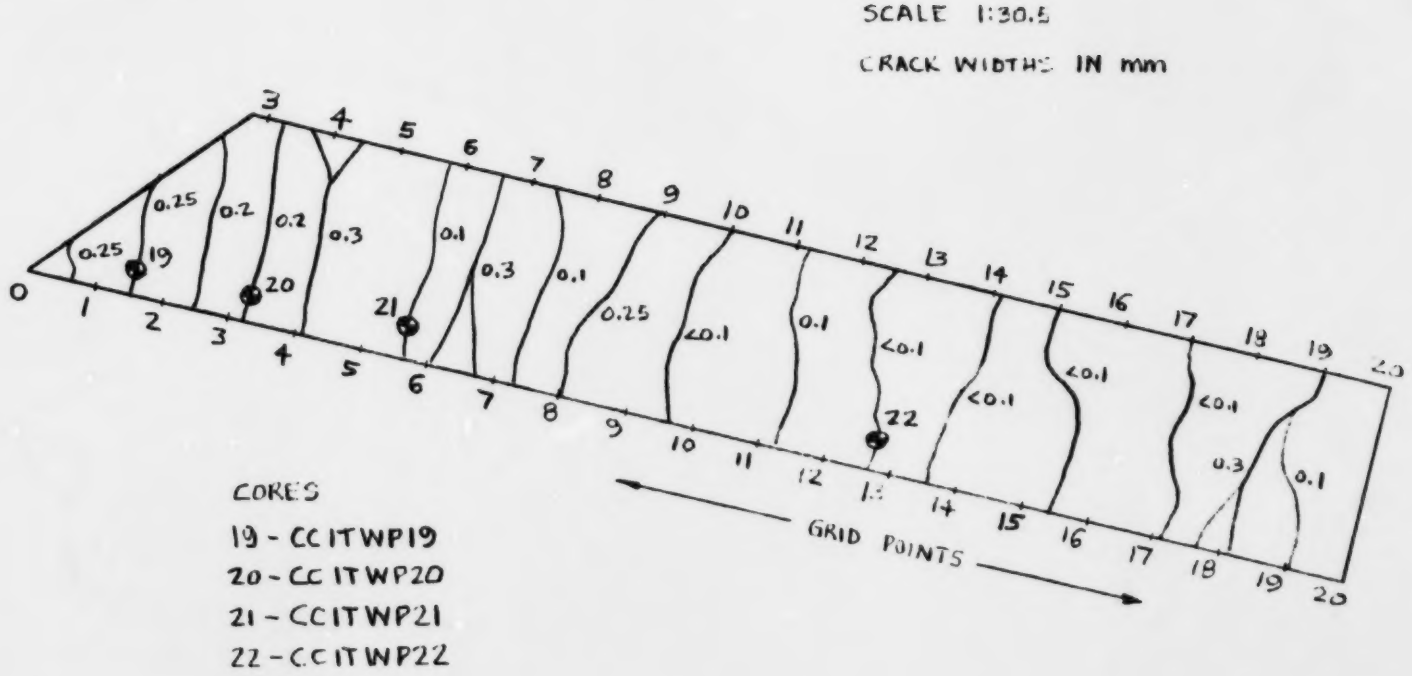
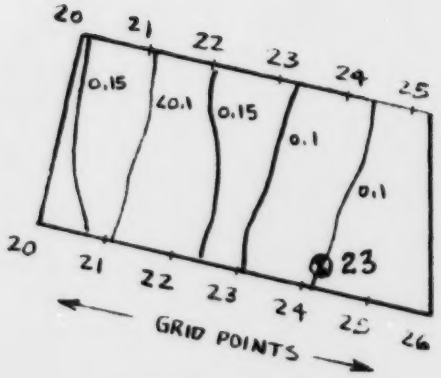


FIGURE 4b

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
2 - INTAKE MIDDLE BAY WEST PIER - CMITWP2
Crack Mapping and Core Locations

SCALE 1:30.5

CRACK WIDTHS IN mm



CORE

23 - CCITWP23

FIGURE 5

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
3 - INTAKE MIDDLE BAY EAST PIER - CMITEP3
Mapping Area

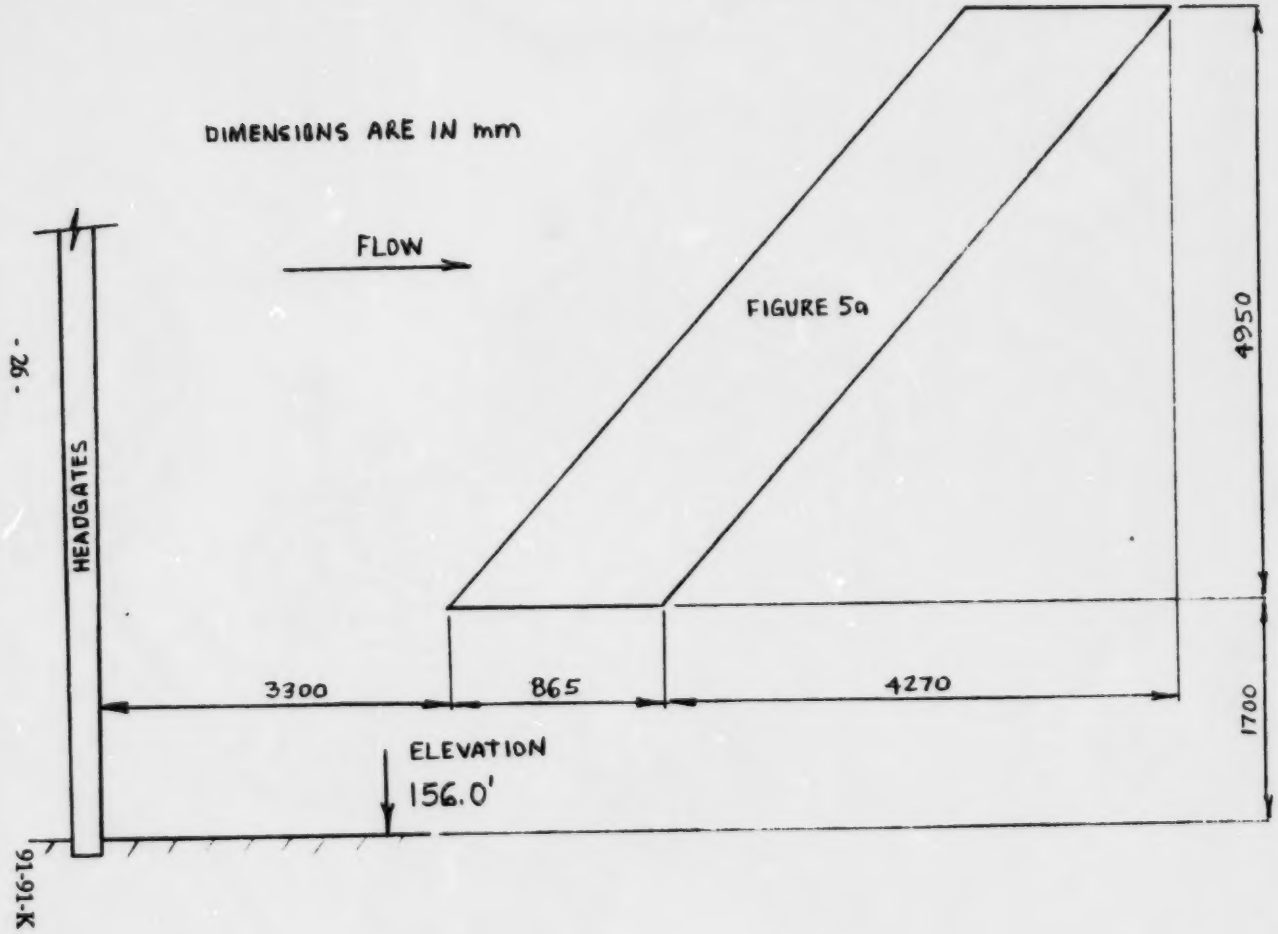


FIGURE 5a

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
3 - INTAKE MIDDLE BAY EAST PIER - CMITEP3
Crack Mapping and Core Locations

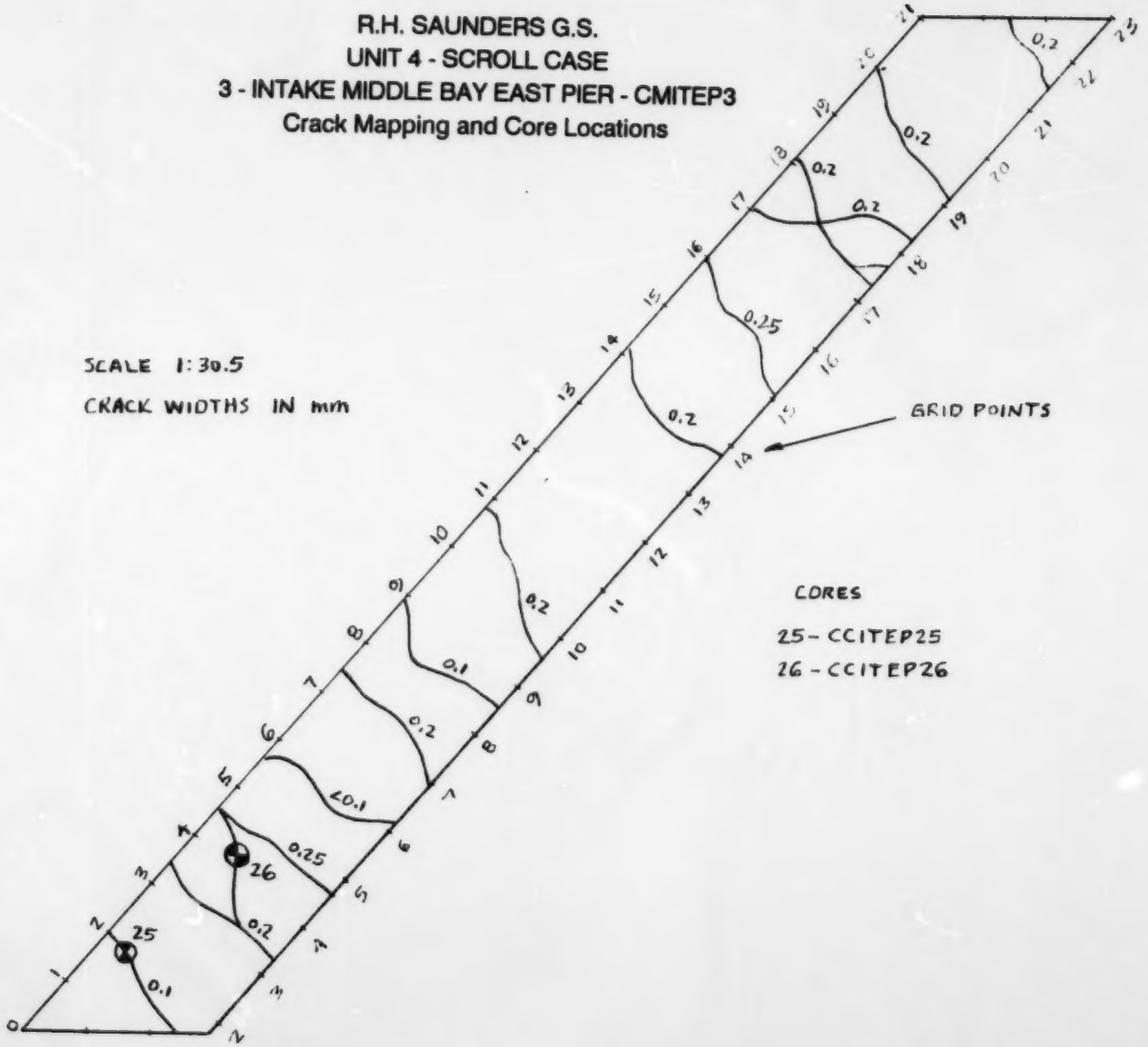


FIGURE 6

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
4 - INTAKE EAST BAY EAST PIER - CMITEP4
Mapping Area

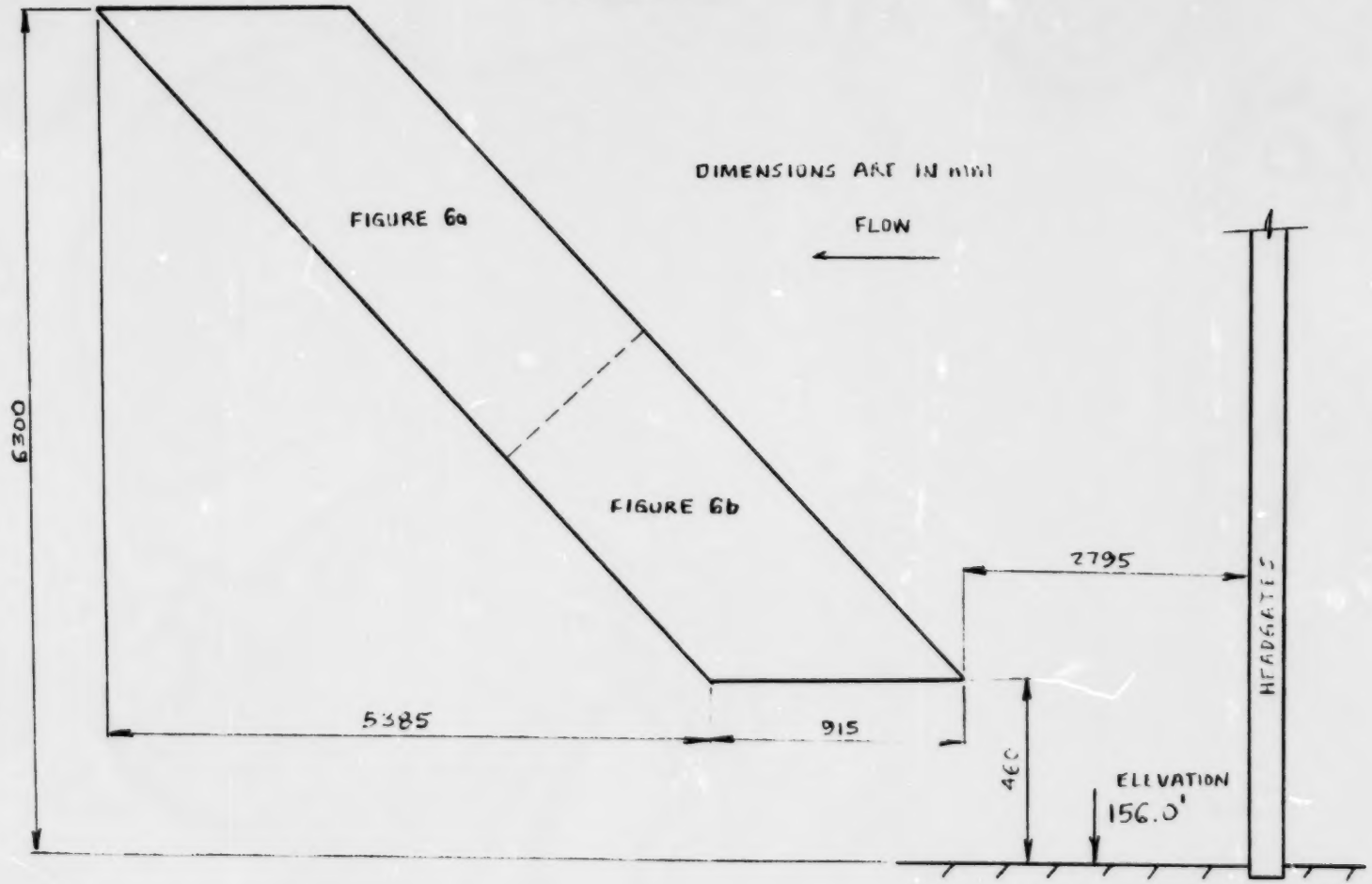
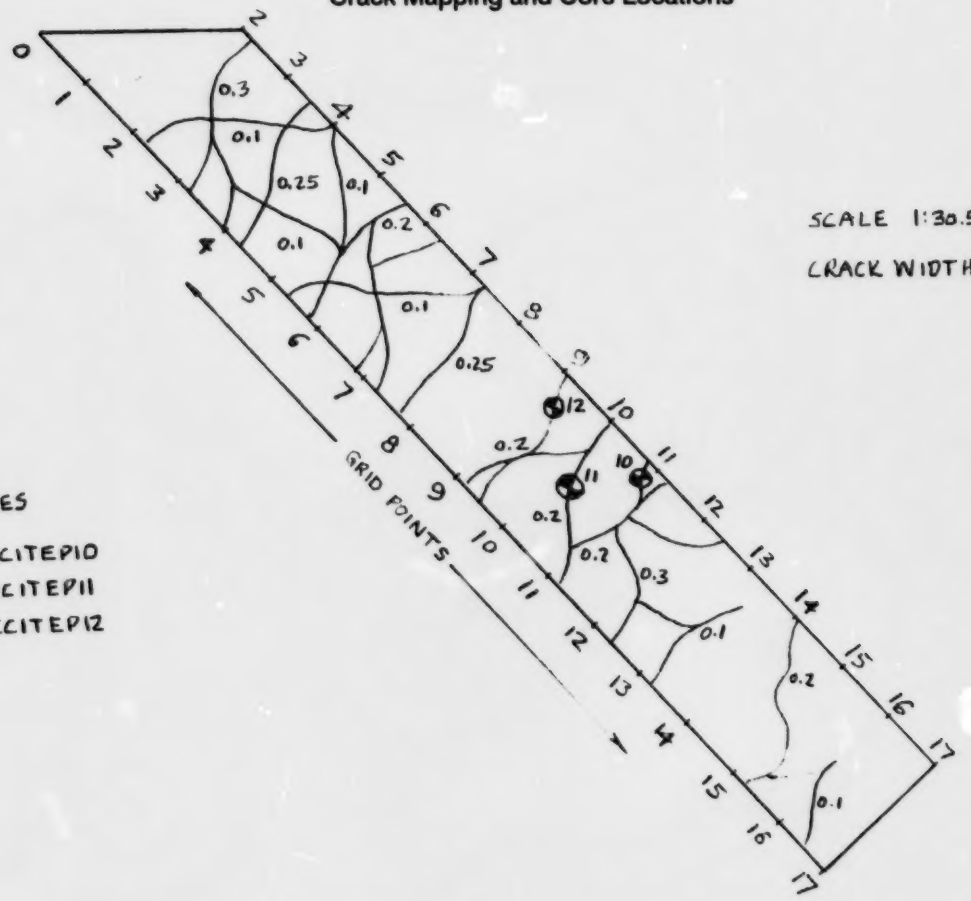


FIGURE 6a

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
4 - INTAKE EAST BAY EAST PIER - CMITEP4
Crack Mapping and Core Locations



SCALE 1:30.5

CRACK WIDTHS IN mm

CORES

10- CCITEP10
11- CCITEP11
12- CCITEP12

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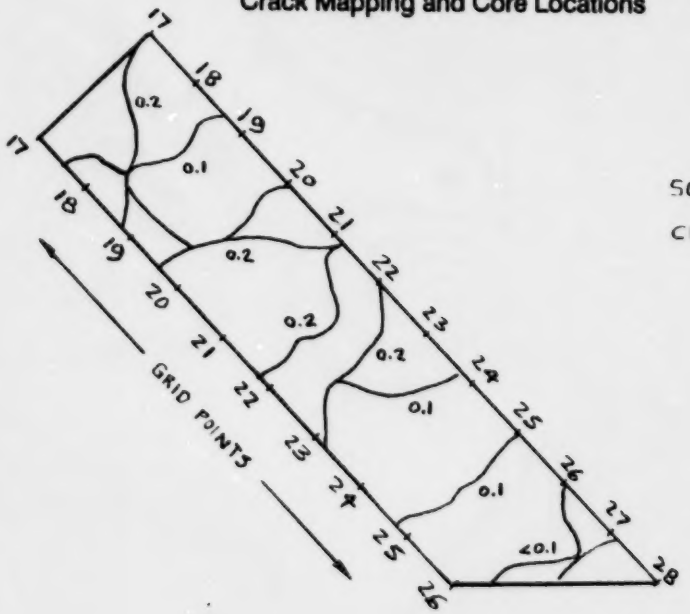
FIGURE 6b

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
4 - INTAKE EAST BAY EAST PIER - CMITEP4
Crack Mapping and Core Locations



SCALE 1:30.5

CRACK WIDTHS IN mm

FIGURE 7

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
5 - INTAKE EAST BAY EAST WALL - CMITEW5
Mapping Area

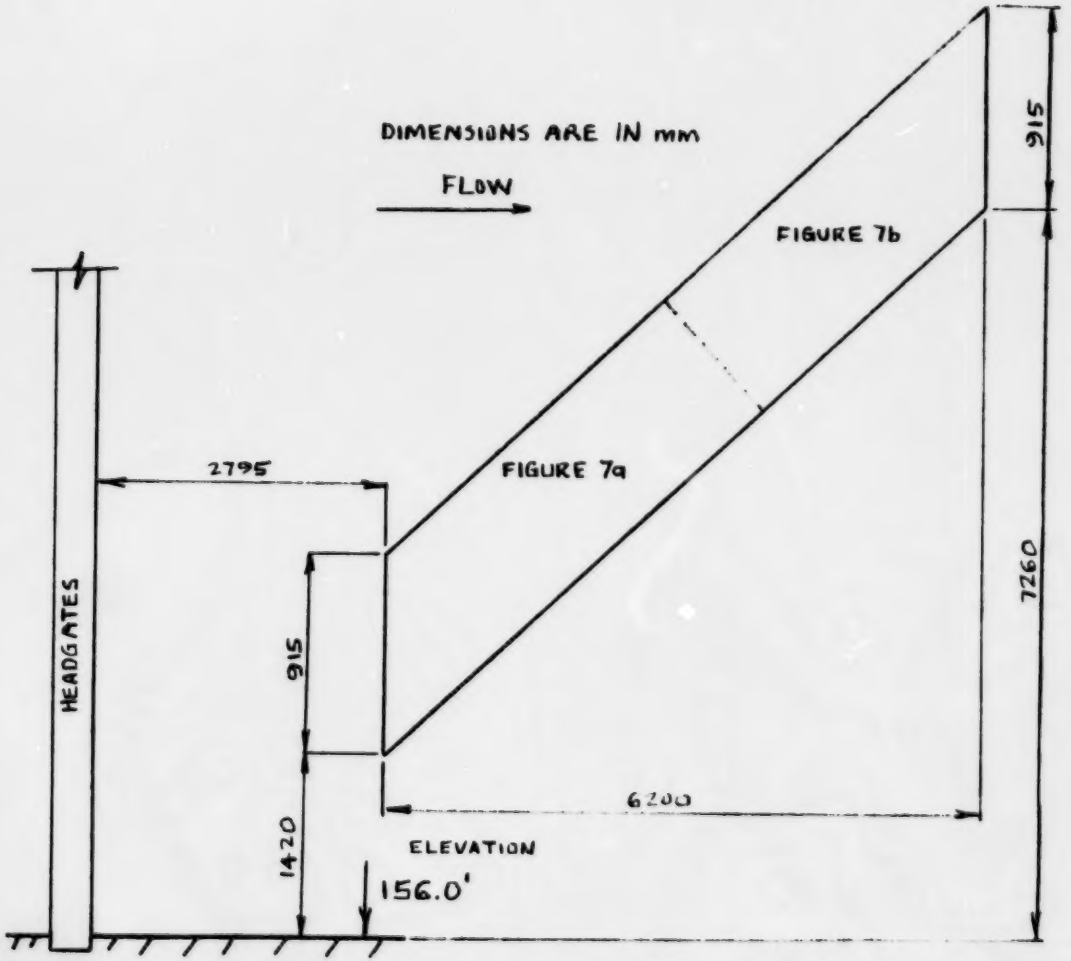


FIGURE 7a

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
5 - INTAKE EAST BAY EAST WALL - CMITEW5
Crack Mapping and Core Locations

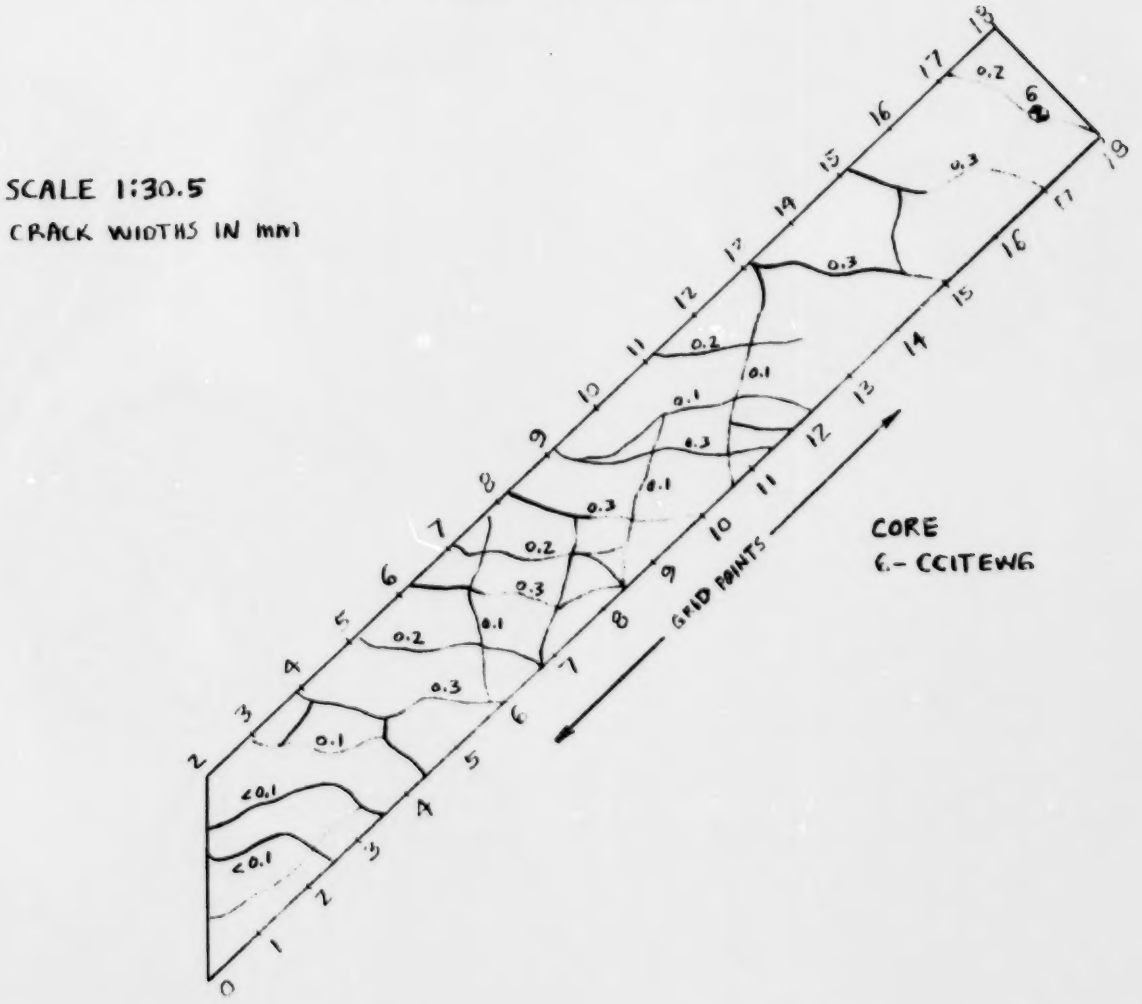


FIGURE 7b

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
5 - INTAKE EAST BAY EAST WALL - CMITEW5
Crack Mapping and Core Locations

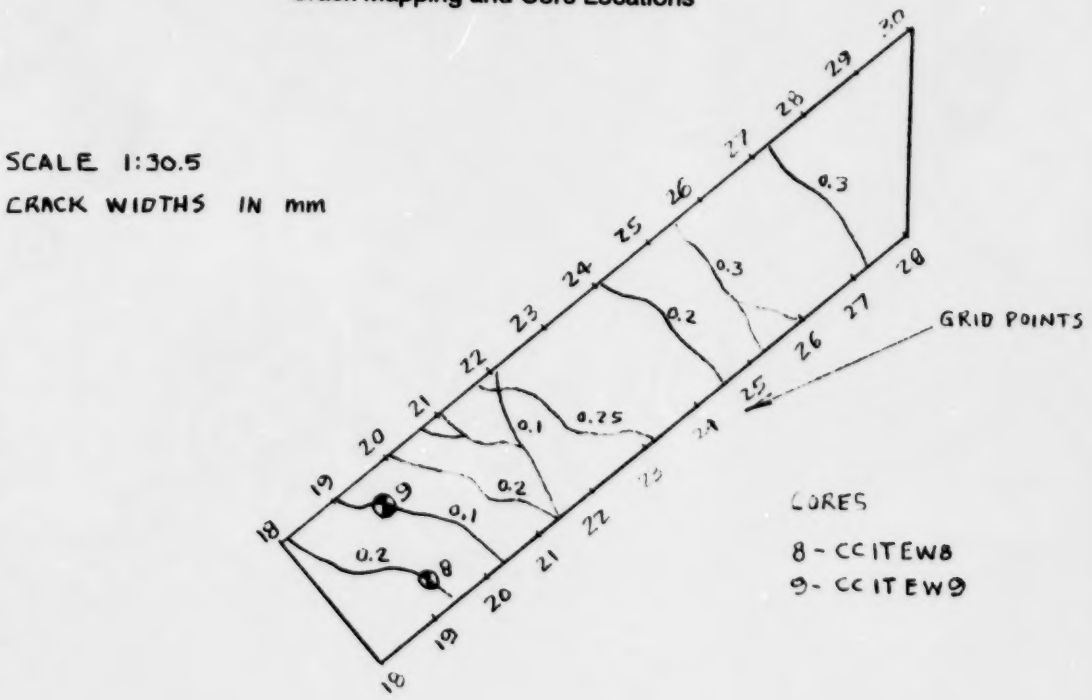
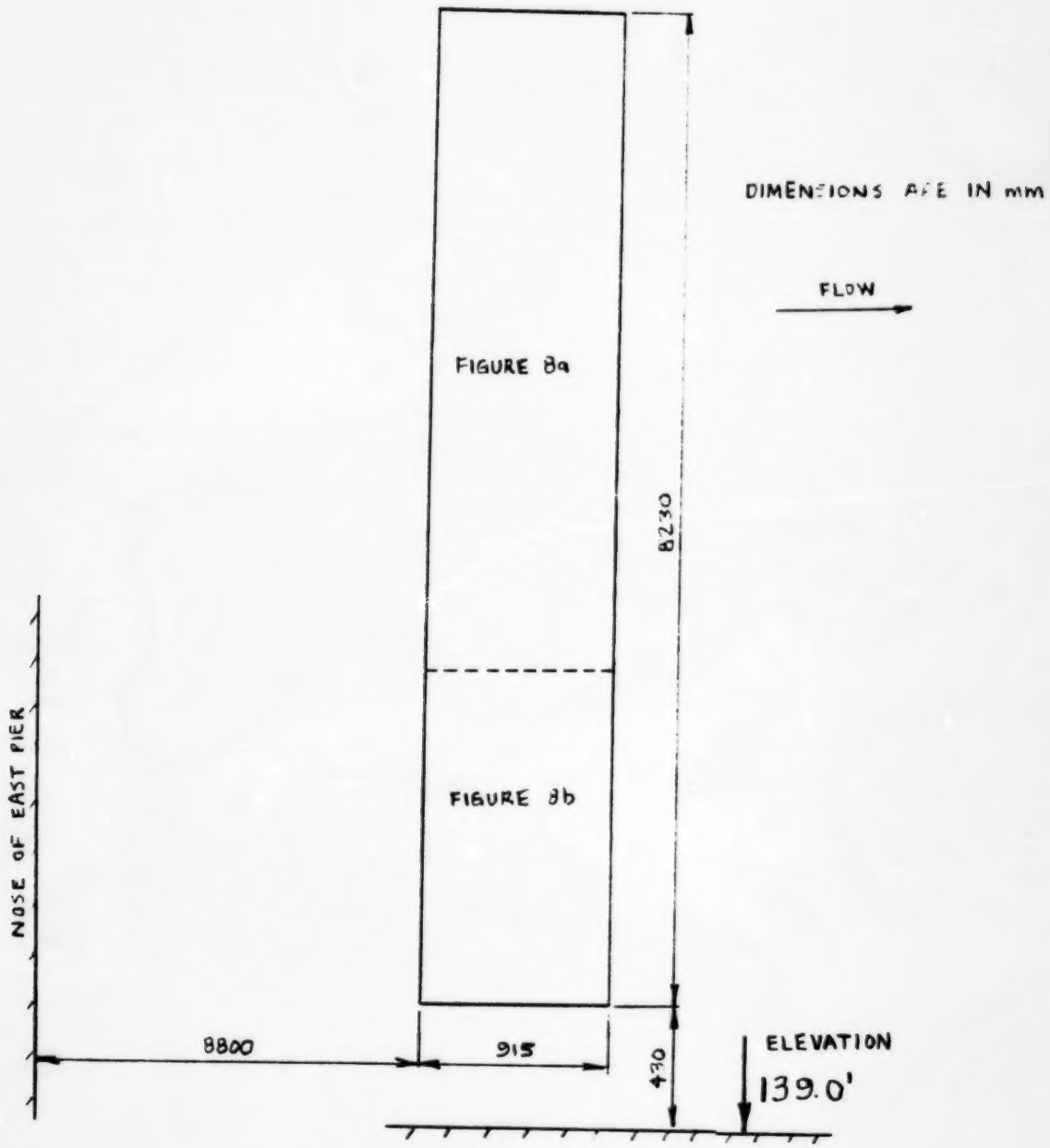


FIGURE 8

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
EAST WALL - CMSCEW6
Mapping Area



91-91-K

FIGURE 8a

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
EAST WALL - CMSCEW6
Crack Mapping and Core Locations

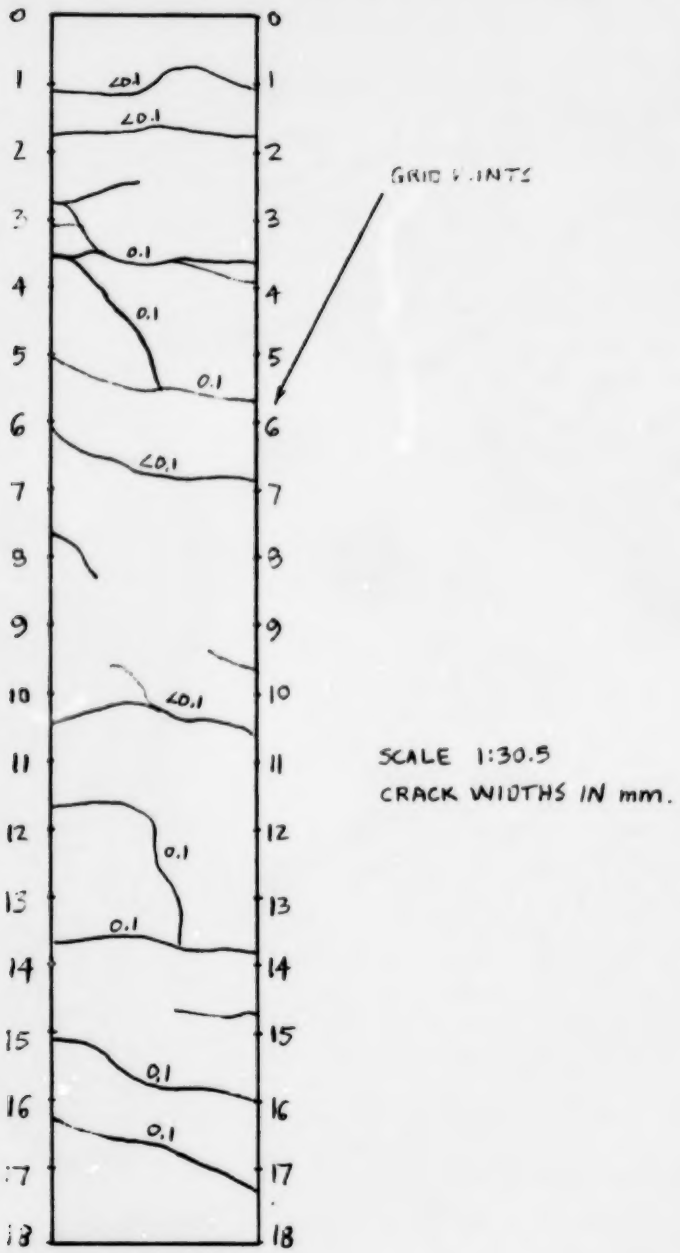
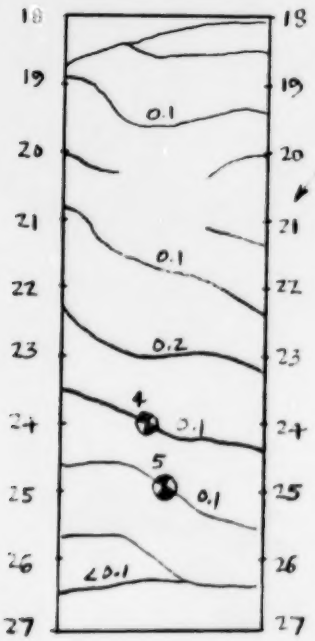


FIGURE 8b

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
EAST WALL - CMSCEW6
Crack Mapping and Core Locations



GRID POINTS

SCALE 1:30.5

CRACK WIDTHS IN mm

CORES

4- CC SC EW 4
5 - CC SC EW 5

FIGURE 9

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
7 – SOUTH WALL - CMSCSW7
Mapping Area

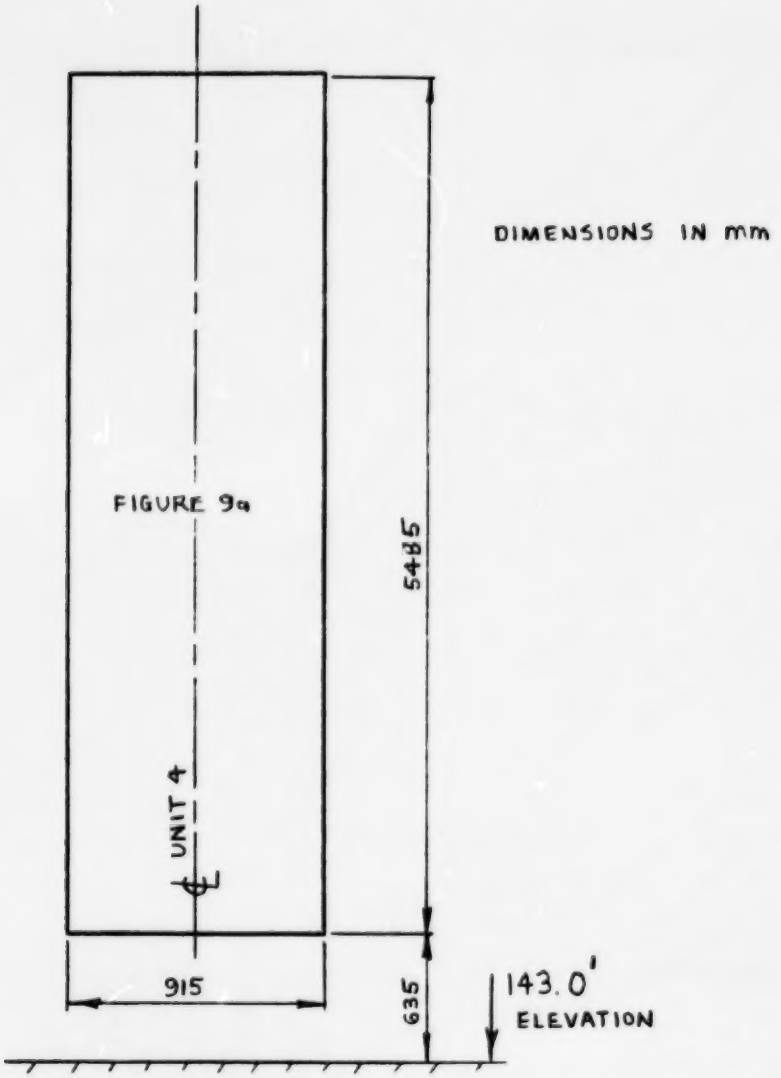


FIGURE 9a

R.H. SAUNDERS G.S.
UNIT 4 - SCROLL CASE
7 - SOUTH WALL - CMSCEW7
Crack Mapping and Core Locations

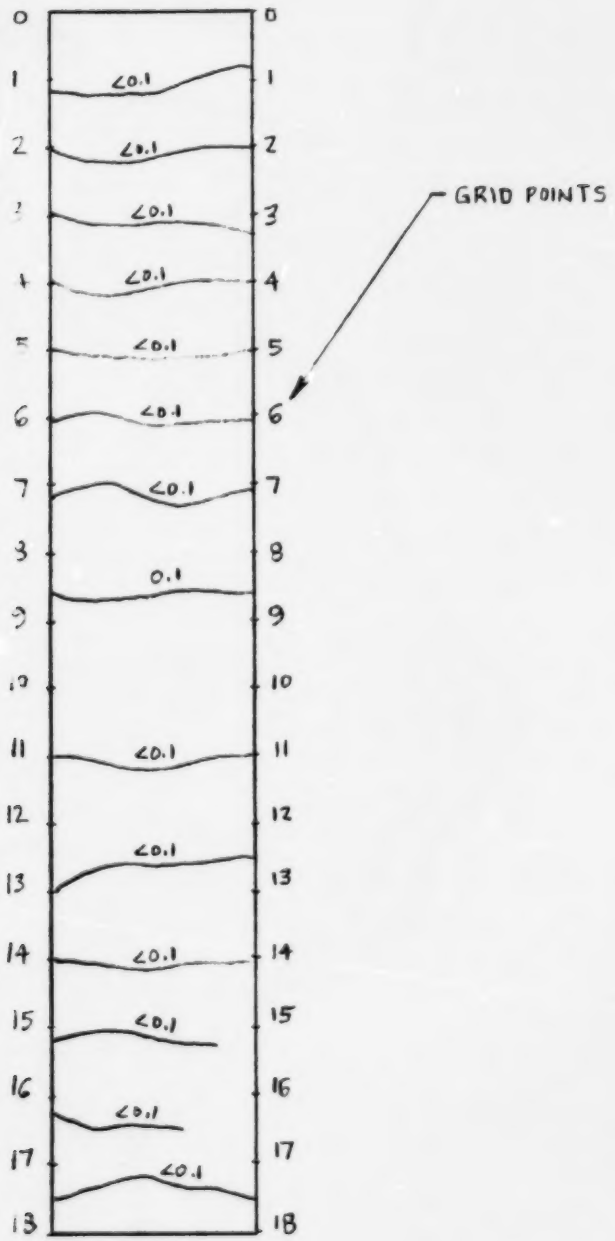


FIGURE 10

R.H. SAUNDERS G.S.
UNIT 4 - DRAFT TUBE
1 - EAST BAY EAST WALL - CMDTEW1
Mapping Area

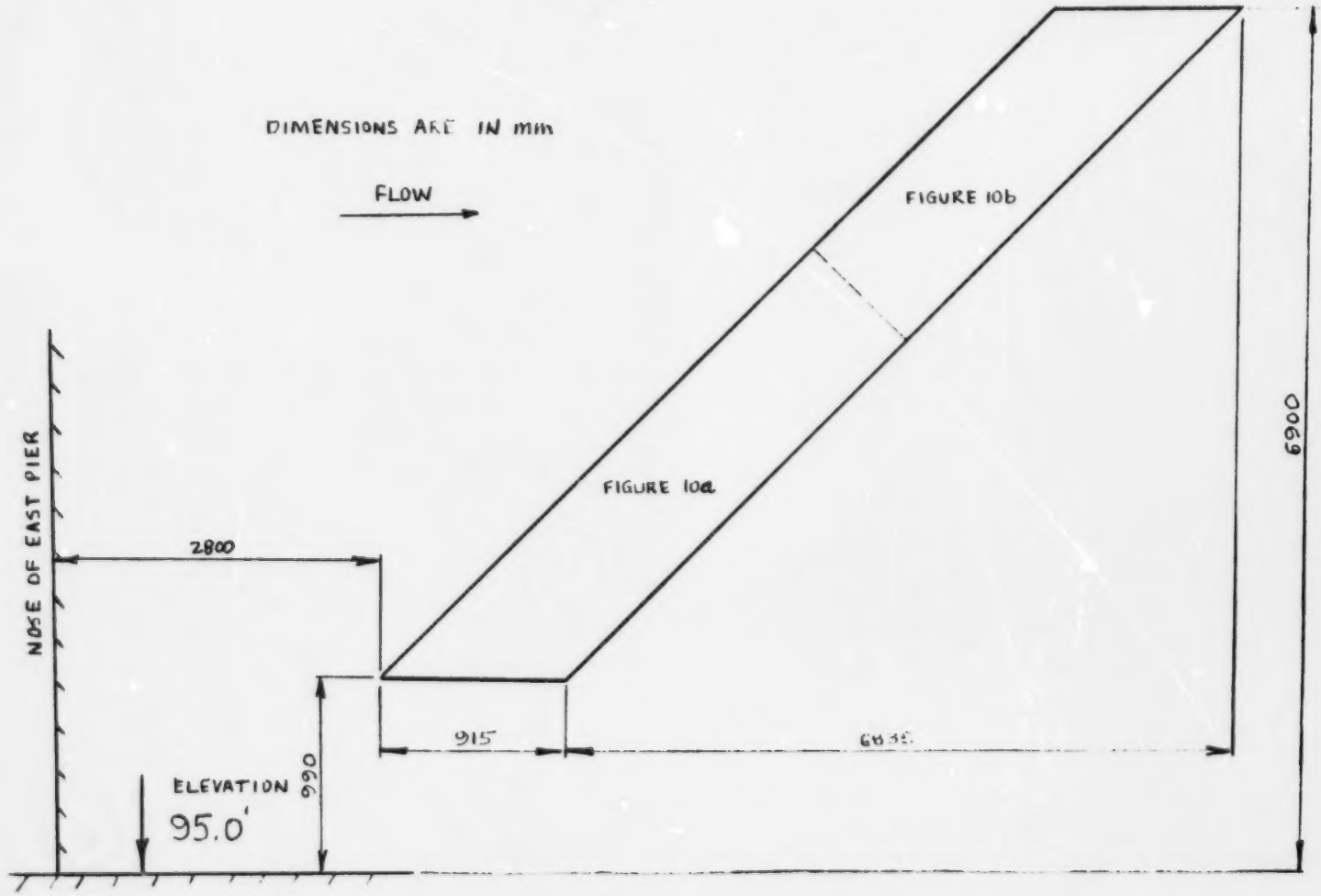


FIGURE 10a

R.H. SAUNDERS G.S.
UNIT 4 - DRAFT TUBE
1 - EAST BAY EAST WALL - CMDTEW1
Crack Mapping and Core Locations

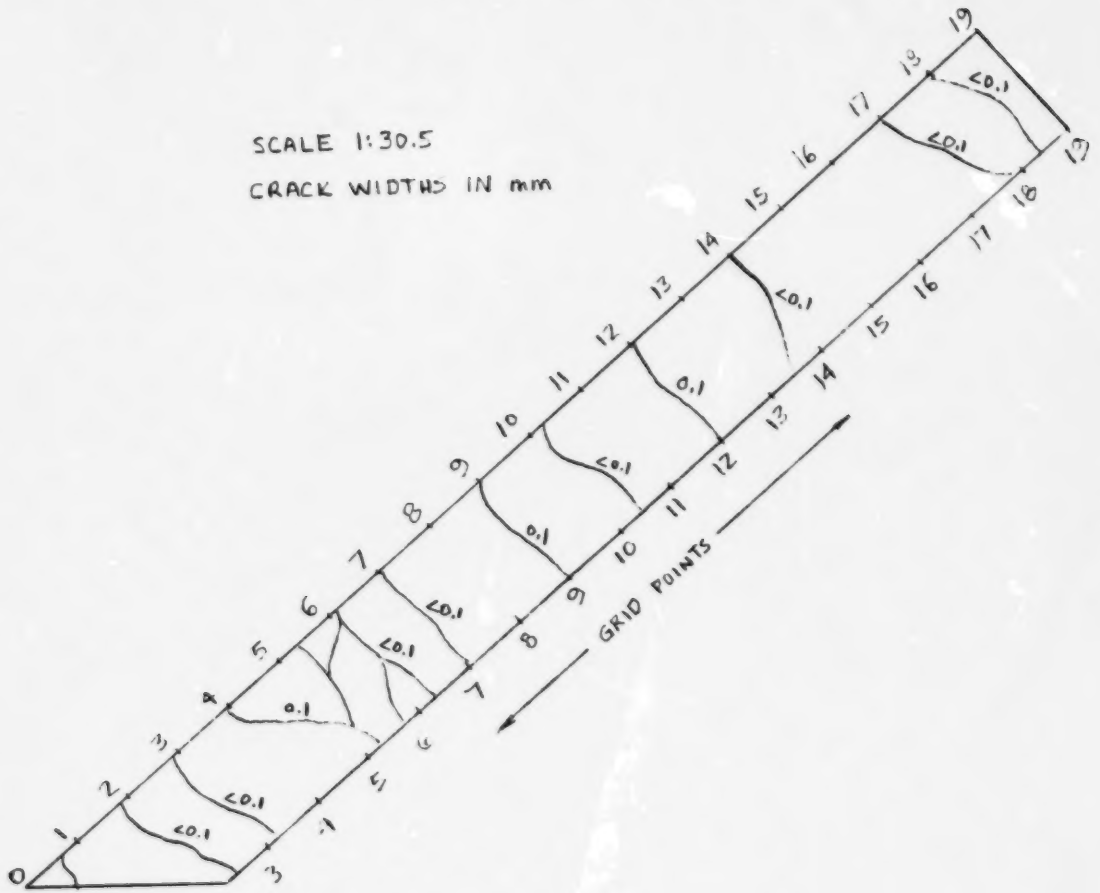


FIGURE 10b

R.H. SAUNDERS G.S.
UNIT 4 - DRAFT TUBE
1 - EAST BAY EAST WALL - CMDTEW1
Crack Mapping and Core Locations

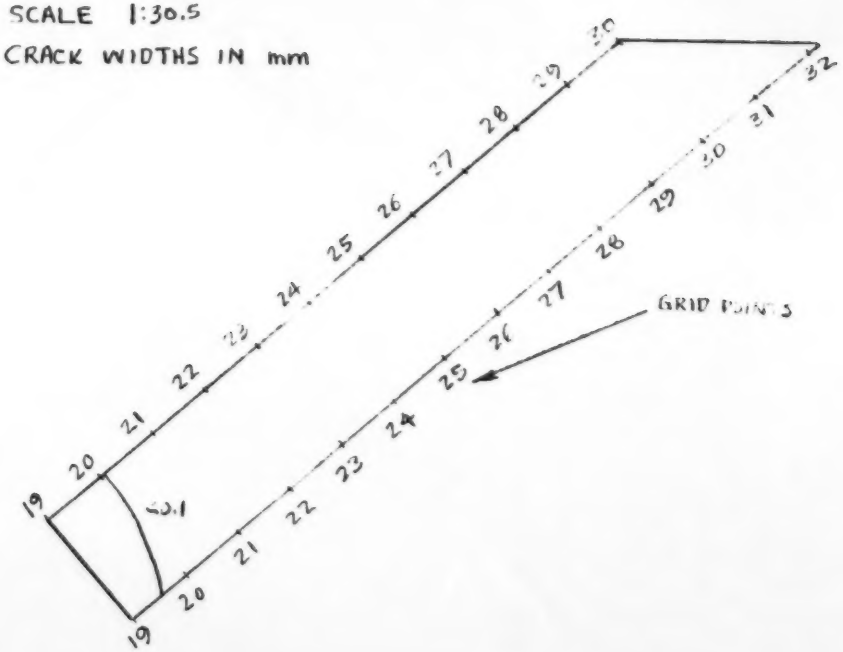


FIGURE 11

R.H. SAUNDERS G.S.
UNIT 4 - DRAFT TUBE
2 - EAST BAY EAST PIER - CMDTEP2
Mapping Area

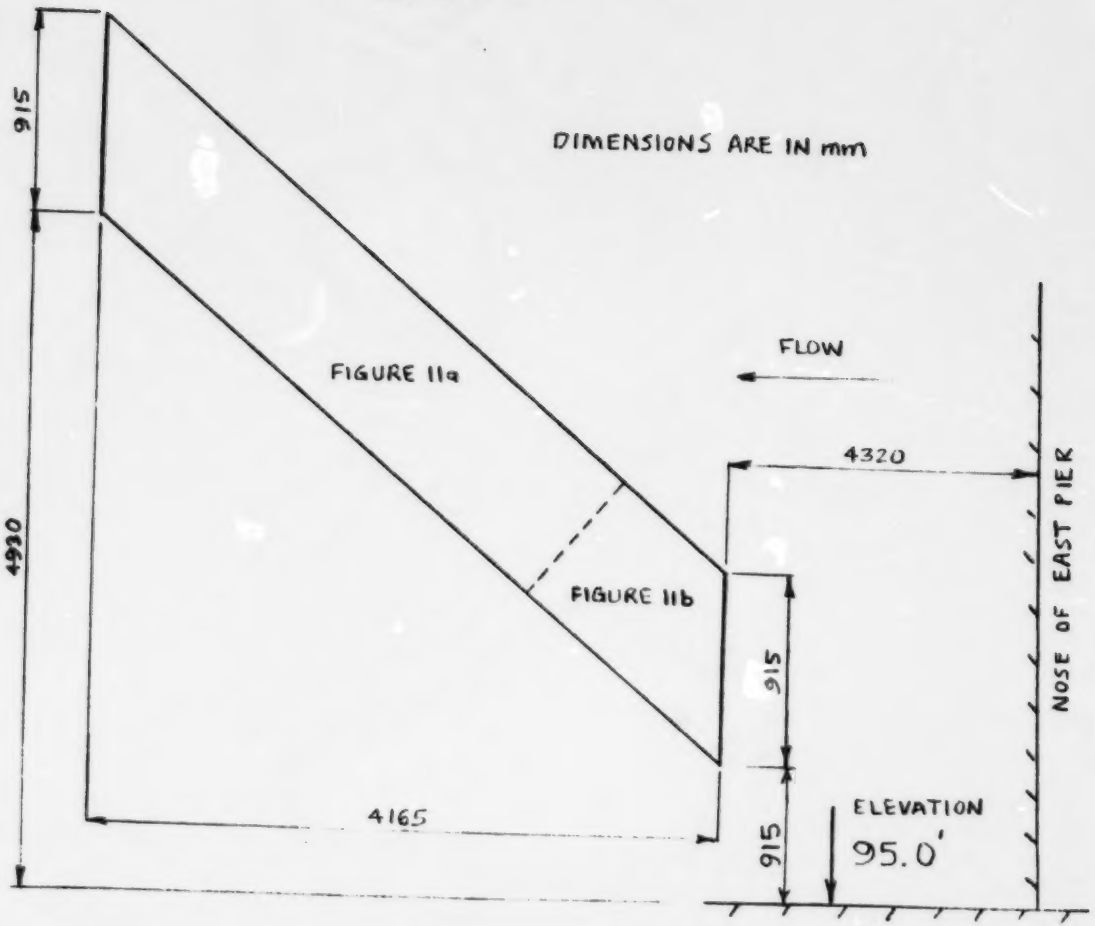


FIGURE 11a

R.H. SAUNDERS G.S.
UNIT 4 - DRAFT TUBE
2 - EAST BAY EAST PIER - CMDTEP2
Crack Mapping and Core Locations

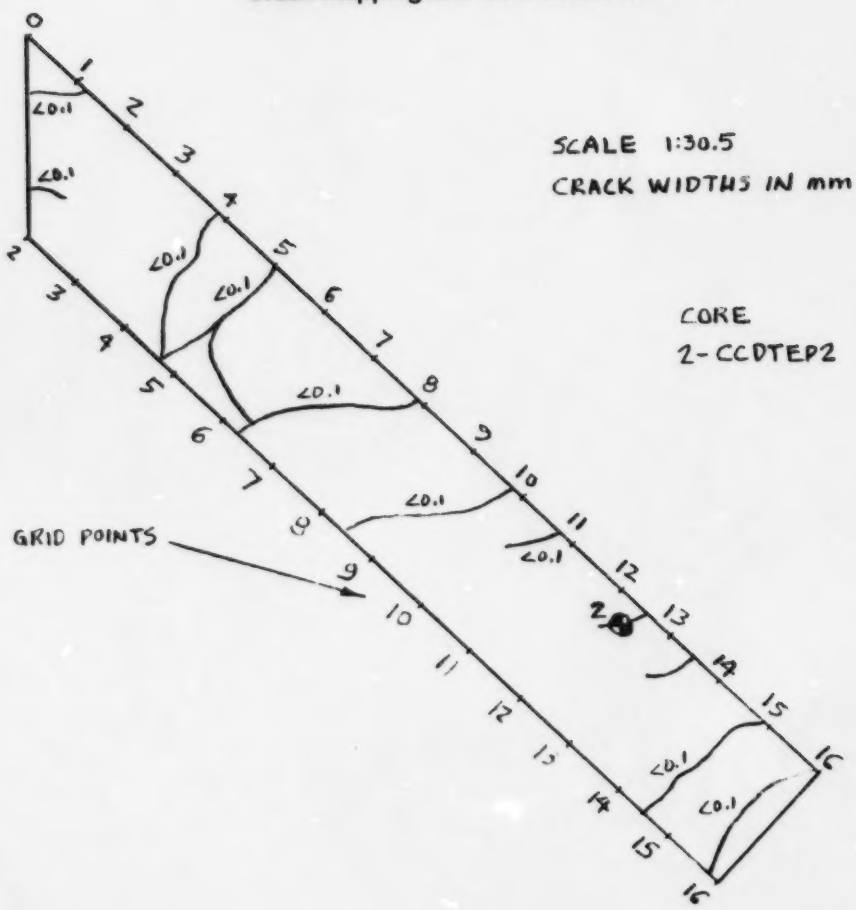
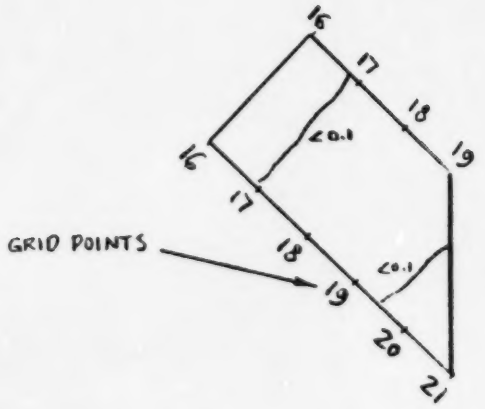


FIGURE 11b

R.H. SAUNDERS G.S.
UNIT 4 - DRAFT TUBE
2 - EAST BAY EAST PIER - CMDTEP2
Crack Mapping and Core Locations

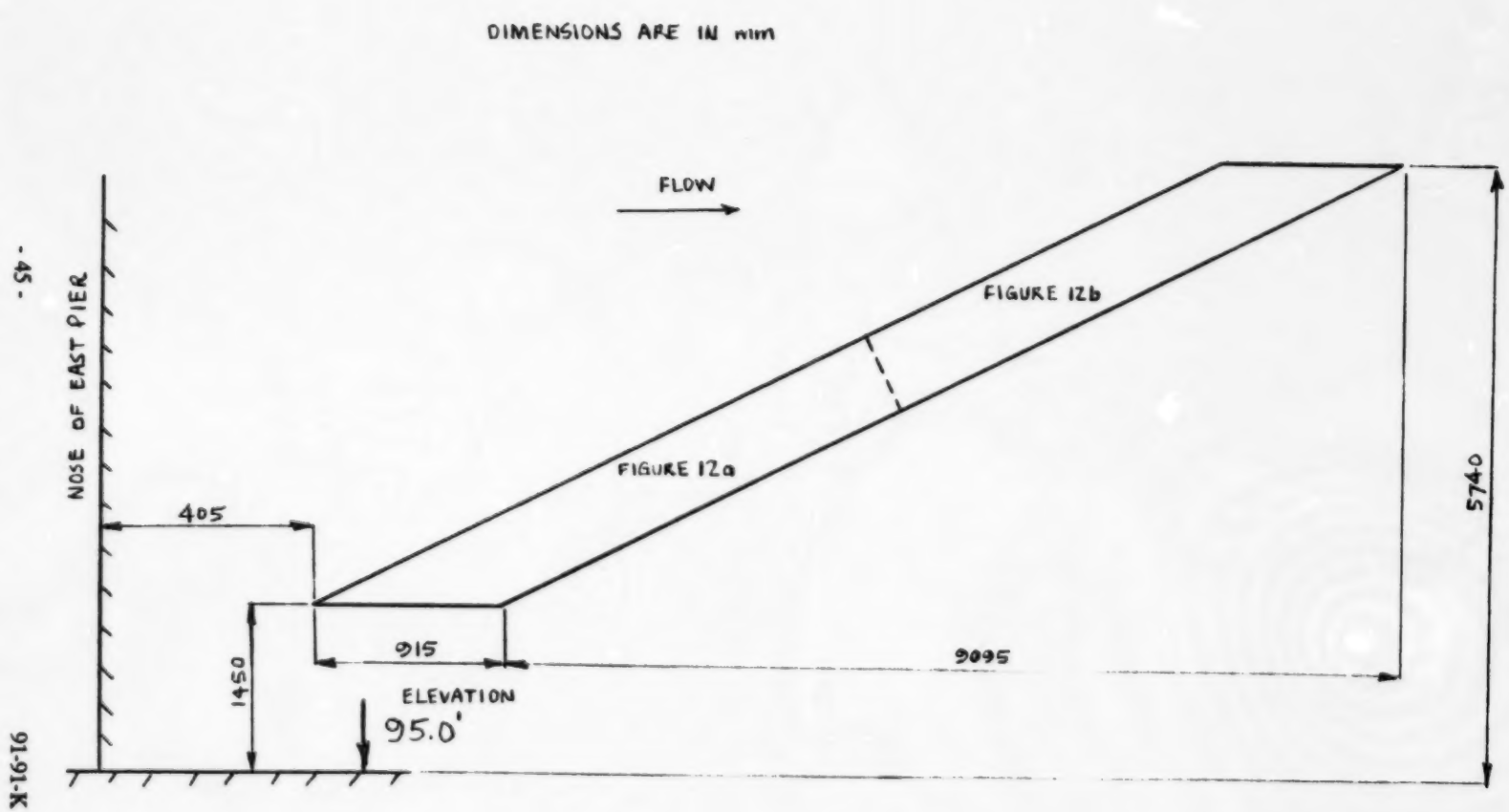


SCALE 1:30.5

CRACK WIDTHS IN mm

FIGURE 12

R.H. SAUNDERS G.S.
UNIT 4 - DRAFT TUBE
3 - MIDDLE BAY EAST PIER - CMDTEP3
Mapping Area



X-16-16

FIGURE 12a

R.H. SAUNDERS G.S.
UNIT 4 - DRAFT TUBE
3 - MIDDLE BAY EAST PIER - CMDTEP3
Crack Mapping and Core Locations

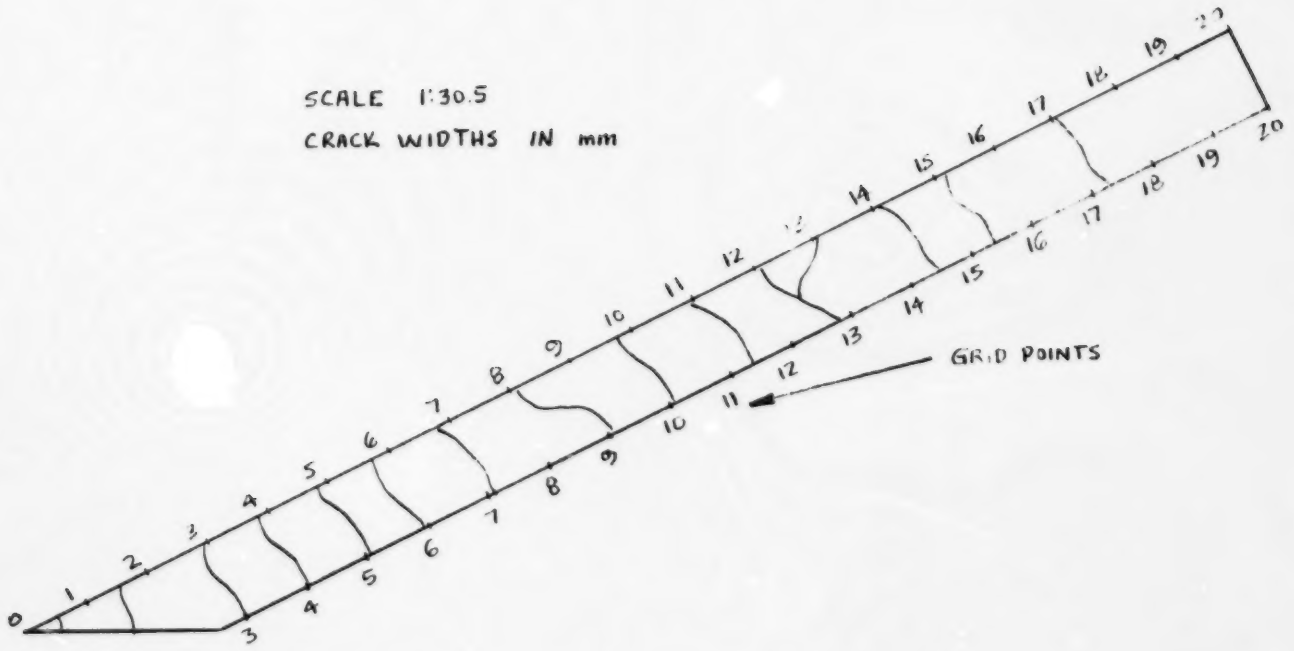


FIGURE 12b

R.H. SAUNDERS G.S.
UNIT 4 - DRAFT TUBE
3 - MIDDLE BAY EAST PIER - CMDTEP3
Crack Mapping and Core Locations

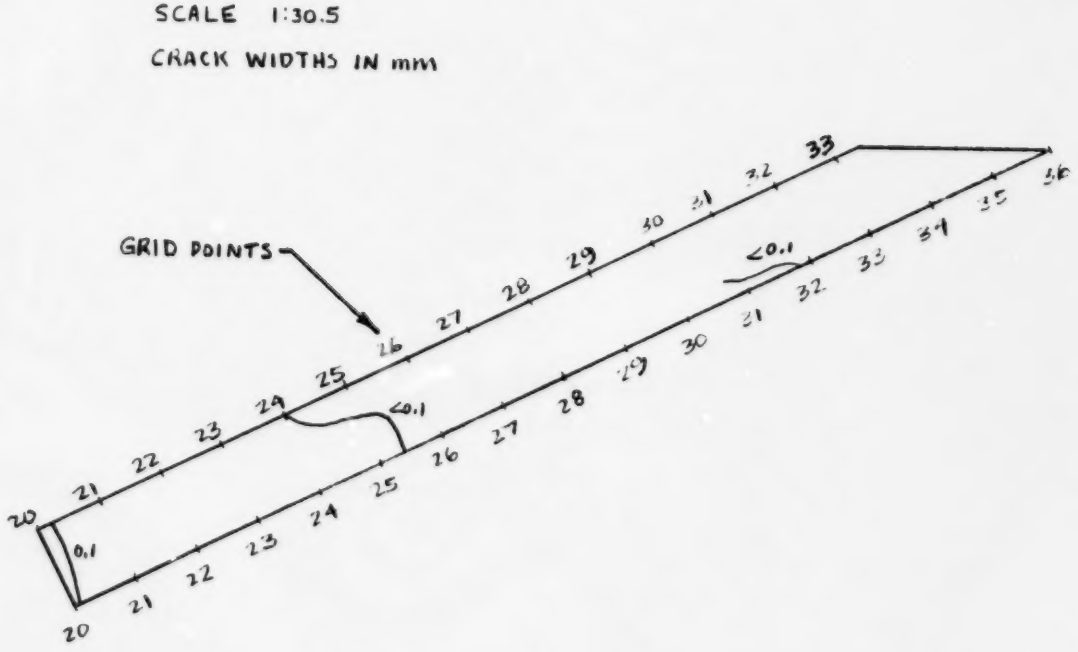


FIGURE 13

R.H. SAUNDERS G.S.
UNIT 4 - DRAFT TUBE
4 - MIDDLE BAY WEST PIER - CMDTWP4
Mapping Area

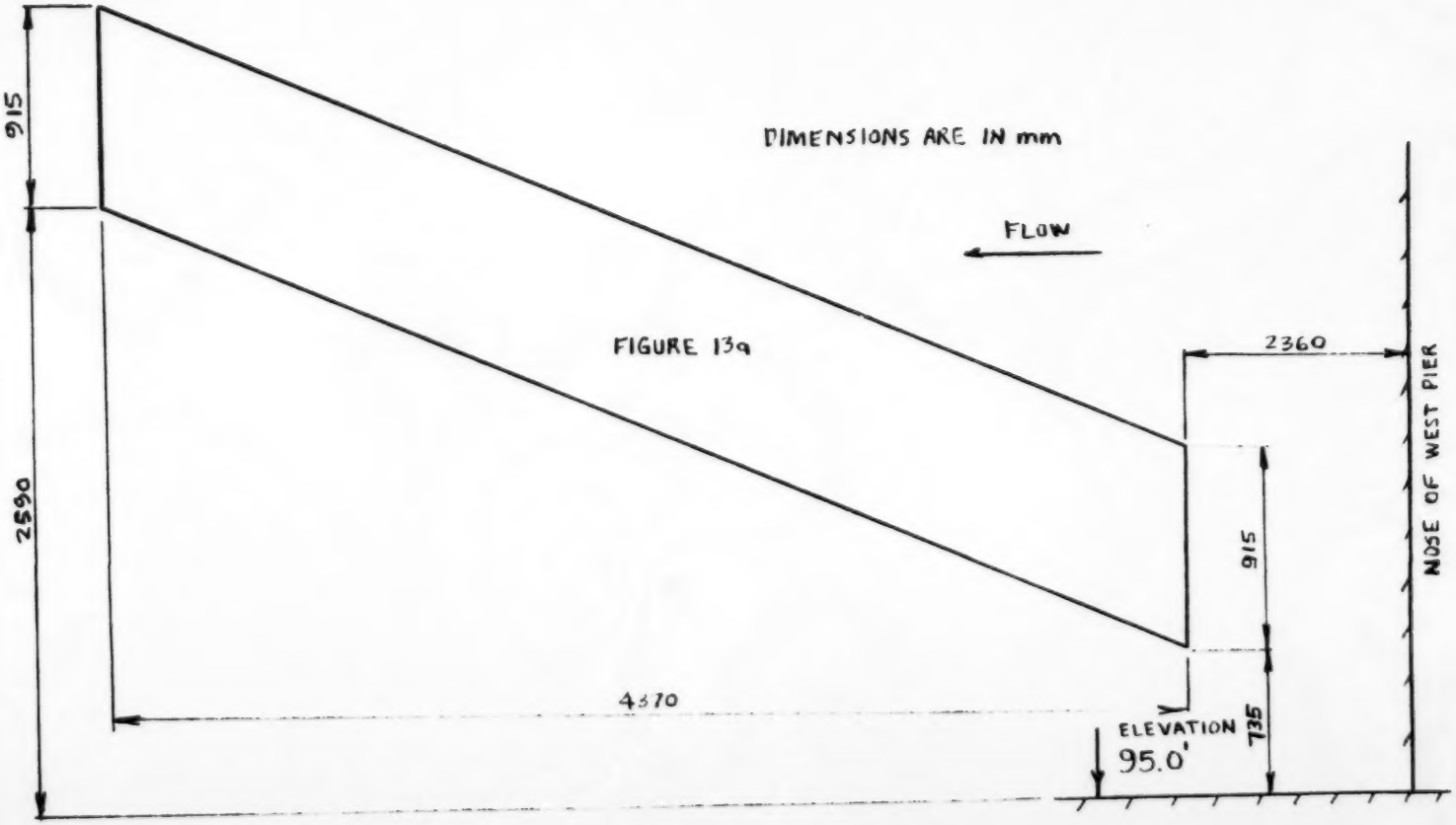
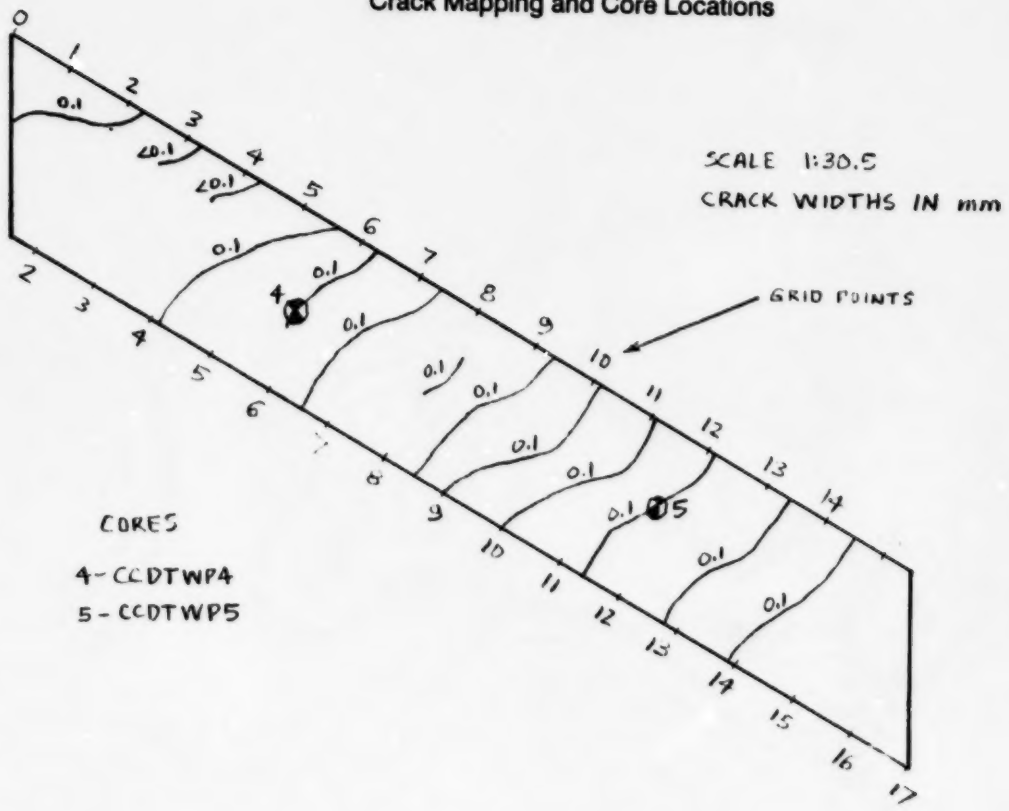


FIGURE 13a

R.H. SAUNDERS G.S.
UNIT 4 - DRAFT TUBE
4 - MIDDLE BAY WEST PIER - CMDTWP4
Crack Mapping and Core Locations



APPENDIX A

R.H. SAUNDERS G.S.
Concrete Movement Investigation
Concrete Core Log

APPENDIX A

R.H. SAUNDERS G.S.
Concrete Core Log

Identification	Location	Section	from-to	Description of Core Sample
Scroll Case - Cores on Cracks				
CCSCEW1	Scroll Case East wall	1-1	0-335 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 200 mm depth
CCSCEW2	Scroll Case East wall	2-1	0-150 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 150 mm depth
CCSCEW3	Scroll Case East wall	3-1	0-150 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 150 mm depth
CCSCEW4	Scroll Case East wall	4-1	0-120 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 120 mm depth
CCSCEW5	Scroll Case East wall	5-1	0-120 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 120 mm depth
Intakes - Cores on Cracks				
CCITEW6	East Intake East wall	6-1	0-165 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 165 mm depth
CCITEW7	East Intake East wall	7-1	0-125 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 125 mm depth
CCITEW8	East Intake East wall	8-1	0-130 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 130 mm depth
CCITEW9	East Intake East wall	9-1	0-145 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 100 mm depth

All cores 100 mm diameter.

APPENDIX A

R.H. SAUNDERS G.S.
Concrete Core Log

Identification	Location	Section	from-to	Description of Core Sample
CCITEP10	East Intake East Pier	10-1	0-140 mm	- fair concrete - maximum nominal aggregate size 20 mm - mortar topping 50 mm thick on surface - crack 0 to 140 mm depth
CCITEP11	East Intake East Pier	11-1	0-150 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 150 mm depth
CCITEP12	East Intake East Pier	12-1	0-80 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 80 mm depth
CCITWW13	West Intake West Wall	13-1	0-150 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 40 mm depth
CCITWW14	West Intake West Wall	14-1	0-300 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 65 mm depth
CCITWW15	West Intake West Wall	15-1	0-140 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 45 mm depth
CCITWW16	West Intake West Wall	16-1	0-100 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 45 mm depth
CCITWW17	West Intake West Wall	17-1	0-180 mm	- good concrete - maximum nominal aggregate size 20 mm - no visible crack
CCITWW18	West Intake West Wall	18-1	0-100 mm	- good concrete - maximum nominal aggregate size 20 mm - small crack on top surface of core
CCITWP19	Middle Intake West Pier	19-1	0-130 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 130 mm depth

All cores 100 mm diameter.

APPENDIX A

R.H. SAUNDERS G.S.
Concrete Core Log

Identification	Location	Section	from-to	Description of Core Sample
CCITWP20	Middle Intake West Pier	20-1	0-110 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 110 mm depth
CCITWP21	Middle Intake West Pier	21-1	0-110 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 110 mm depth
CCITWP22	Middle Intake West Pier	22-1	0-230 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 30 mm depth
CCITWP23	Middle Intake West Pier	23-1	0-230 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 20 mm depth
CCITEP24	Middle Intake East Pier	24-1	0-110 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 110 mm depth
CCITEP25	Middle Intake East Pier	25-1	0-160 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 50 mm depth
CCITEP26	Middle Intake East Pier	26-1	0-240 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 80 mm depth
CCITEP27	East Intake East Pier	27-1	0-130 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 130 mm depth
CCITEW28	East Intake East Wall	28-1	0-120 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 120 mm depth
CCITEP29	East Intake East Pier	29-1	0-100 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 100 mm depth

All cores 100 mm diameter.

APPENDIX A

R.H. SAUNDERS G.S.
Concrete Core Log

Identification	Location	Section	from-to	Description of Core Sample
Draft Tube - Cores on Cracks				
CCDTEW1	Draft Tube East Bay East Wall	1-1	0-160 mm	- good concrete - maximum nominal aggregate size 25 mm - crack 0 to 160 mm depth
CCDTEP2	Draft Tube East Bay East Pier	2-1	0-270 mm	- good concrete - maximum nominal aggregate size 25 mm - crack 0 to 30 mm depth
CCDTEP3	Draft Tube Middle Bay East Pier	3-1	0-190 mm	- good concrete - maximum nominal aggregate size 25 mm - crack 0 to 190 mm depth
CCDTWP4	Draft Tube Middle Bay West Pier	4-1	0-250 mm	- good concrete - maximum nominal aggregate size 25 mm - crack 0 to 60 mm depth
CCDTWP5	Draft Tube Middle Bay West Pier	5-1	0-270 mm	- good concrete - maximum nominal aggregate size 25 mm - crack 0 to 90 mm depth
Gallery 180 Level - Cores on Cracks				
CC22N1	Gallery 180 Level Upstream Wall	1-1	-	- No core taken.
CC22N2	Gallery 180 Level Upstream Wall	2-1	-	- No core taken.
Generator Room - Cores on Cracks				
CC55E3	Generator Room East Wall	3-1	0-95 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 95 mm depth - core broken in two because of crack
CC44W4	Generator Room West Wall	4-1	0-120 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 120 mm depth - core broken in two because of crack

All cores 100 mm diameter.

APPENDIX A

R.H. SAUNDERS G.S.
Concrete Core Log

Identification	Location	Section	from-to	Description of Core Sample
S2 Level - Cores on Cracks				
CC66S5	S2 Level Upstream Wall	5-1	0-150 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 150 mm depth
CC66S6	S2 Level Upstream Wall	6-1	0-275 mm	- poor concrete - poor aggregate distribution - maximum nominal aggregate size 20 mm - crack 0 to 70 mm depth
S4 Level - Cores on Cracks				
CC66S7	S4 Level Upstream Wall	7-1	0-90 mm	- good concrete - maximum nominal aggregate size 25 mm - crack 0 to 90 mm depth
Inspection Tunnel - Cores on Cracks				
CCIG6	Inspection Tunnel Upstream Wall	6-1	0-280	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 120 mm depth
CCIG8	Inspection Tunnel Upstream Wall	8-1	0-290	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 100 mm depth
CCIG9	Inspection Tunnel Downstream Wall	9-1	0-230	- good concrete - maximum nominal aggregate size 20 mm

All cores 100 mm diameter.

APPENDIX A

R.H. SAUNDERS G.S.
Concrete Core Log

Identification	Location	Section	from-to	Description of Core Sample
			Scroll Case - Cores on Construction Joints	
JCSCEW1	Scroll Case East Wall	1-1	0-210 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core
		1-2	210-390 mm	- " " "
		1-3	390-640 mm	- " " "
		1-4	640-1000 mm	- " " " - joint ends at 1000 mm
		1-5	1000-1190 mm	- good concrete - maximum nominal aggregate size 25 mm - no construction joint
		1-6	1190-1300 mm	- " " "
		1-7	1300-1500 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core
JCSCEW2	Scroll Case East Wall	2-1	0-230 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core
		2-2	230-410 mm	- " " "
		2-3	410-650 mm	- " " "
		2-4	650-800 mm	- " " "
		2-5	800-1000 mm	- " " "
		2-6	1000-1330 mm	- good concrete - maximum nominal aggregate size 25 mm - no construction joint

All cores 100 mm diameter.

APPENDIX A

R.H. SAUNDERS G.S.
Concrete Core Log

Identification	Location	Section	from-to	Description of Core Sample
JCSCEW3	Scroll Case East Wall	3-1	0-230 mm	- good concrete - maximum nominal aggregate size 25 mm - 35 mm rebar located at 200 mm depth - construction joint extends entire length of core
		3-2	230-330 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core
		3-3	330-450 mm	- " " "
		3-4	450-570 mm	- " " "
			570-660 mm	- rubble with a construction joint
		3-5	660-920 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core
		3-6	920-1000 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint perpendicular to drilling at 1000 mm
		3-7	1000-1140 mm	- fair concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core
			1140-1160 mm	- water stop
		3-8	1160-1330 mm	- fair concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core - construction joint perpendicular to drilling at 1330 mm
JCSCWW4	Scroll Case West Wall	4-1	0-190 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core
		4-2	190-380 mm	- " " "
		4-3	380-620 mm	- " " "
		4-4	620-840 mm	- " " "

All cores 100 mm diameter.

APPENDIX A

R.H. SAUNDERS G.S.
Concrete Core Log

Identification	Location	Section	from-to	Description of Core Sample
		4-5	840-1000 mm	- good concrete - construction joint extends entire length of core - construction joint open - construction joint ends at 1000 mm
		4-6	1000-1335 mm	- good concrete - maximum nominal aggregate size 25 mm
JCSCWW5	Scroll Case West Wall	5-1	0-170 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core
		5-2	170-370 mm	- " " " - 35 mm diameter rebar located at 280 mm depth
		5-3	370-600 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core - 35 mm diameter rebar located at 370 mm depth
		5-4	600-840 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core
		5-5	840-990 mm	- " " "
		5-6	990-1220 mm	- good concrete - maximum nominal aggregate size 25 mm - crack at 990 mm to a depth of 1090 mm
JCSCSW6	Scroll Case South Wall	6-1	0-230 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core - 35 mm diameter rebar located at 170 mm depth
		6-2	230-370 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core

All cores 100 mm diameter.

APPENDIX A

R.H. SAUNDERS G.S.
Concrete Core Log

Identification	Location	Section	from–to	Description of Core Sample
		6–3	370–600 mm	– good concrete – maximum nominal aggregate size 25 mm – 35 mm diameter rebar located at 370 mm depth – construction joint ends at 570 mm
JCSCSW7	Scroll Case South Wall	7–1	0–160 mm	– good concrete – maximum nominal aggregate size 25 mm – construction joint extends entire length of core
		7–2	160–430 mm	– " " "
		7–3	430–620 mm	– " " "
		7–4	620–870 mm	– " " "
Draft Tube – Cores on Construction Joints				
JCDTEW8	Draft Tube East Wall	8–1	0–130 mm	– good concrete – maximum nominal aggregate size 25 mm – construction joint extends entire length of core
		8–2	130–300 mm	– " " "
		8–3	300–580 mm	– " " "
		8–4	580–720 mm	– " " "
		8–5	720–980 mm	– " " "
JCDTEW9	Draft Tube East Wall	9–1	0–130 mm	– good concrete – maximum nominal aggregate size 25 mm – construction joint extends entire length of core
		9–2	130–360 mm	– " " "
		9–3	360–630 mm	– " " "
JCDTEP10	Draft Tube East Bay East Pier	10–1	0–200 mm	– good concrete – maximum nominal aggregate size 20 mm – construction joint extends entire length of core
		10–2	200–430 mm	– " " " – 20 mm diameter rebar located at 360 mm depth

All cores 100 mm diameter.

APPENDIX A

R.H. SAUNDERS G.S.
Concrete Core Log

Identification	Location	Section	from-to	Description of Core Sample
		10-3	430-660 mm	- good concrete - maximum nominal aggregate size 20 mm - construction joint extends entire length of core
JCDTEP11	Draft Tube Middle Bay East Pier	11-1	1-190 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core
		11-2	190-520 mm	- " " "
		11-3	520-800 mm	- " " "
JCDTEP12	Draft Tube Middle Bay East Pier	12-1	0-250 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core
		12-2	250-500 mm	- " " "
		12-3	500-770 mm	- " " "
Gallery 180 Level - Cores on Construction Joints				
JC22N1	Gallery 180 Level Upstream Wall	1-1	-	- No core taken.
JC22N2	Gallery 180 Level Upstream Wall	2-1	-	- No core taken.
Generator Room - Cores on Construction Joints				
JC44W3	Generator Room West Wall	3-1	0-160 mm	- good concrete - maximum nominal aggregate size 20 mm - crack 0 to 160 mm depth - core broken in two because of crack

All cores 100 mm diameter.

APPENDIX A

R.H. SAUNDERS G.S.
Concrete Core Log

Identification	Location	Section	from-to	Description of Core Sample
S2 Level - Cores on Construction Joints				
JC66S4	S2 Level Upstream Wall	4-1	0-320 mm	- good concrete - maximum nominal aggregate size 20 mm - construction joint extends entire length of core - 20 mm diameter rebar located at 320 mm depth
JC66S9	S2 Level Upstream Wall	9-1	0-270 mm	- good concrete - maximum nominal aggregate size 20 mm - construction joint extends entire length of core
		9-2	270-490 mm	- " " "
		9-3	490-650 mm	- " " "
		9-4	650-980 mm	- " " "
		9-5	980-1300 mm	- " " "
		9-6	1300-1665 mm	- " " "
S4 Level - Cores on Construction Joints				
JC66S5	S4 Level Upstream Wall	5-1	0-260 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core
		5-2	260-552 mm	- " " "
		5-3	552-820 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint ends at 570 mm - horizontal pipe intersected at 774 mm
Inspection Tunnel - Cores on Cracks				
JC1G8	Inspection Tunnel Downstream Wall	8-1	0-100 mm	- good concrete - maximum nominal aggregate size 25 mm - construction joint extends entire length of core
		8-2	100-225 mm	- " " "

All cores 100 mm diameter.

APPENDIX A

R.H. SAUNDERS G.S.
Concrete Core Log

Identification	Location	Section	from-to	Description of Core Sample
		8-3	225-530 mm	- " " "
		8-4	530-800 mm	- " " "
		8-5	800-1070 mm	- " " "
		8-6	1070-1330 mm	- " " "
Scroll Case - Cores				
CSCSW1	Scroll Case Downstream Wall	1-1	0-200 mm	- good concrete - maximum nominal aggregate size 25 mm - 35 mm diameter rebar located at 140 mm depth
		1-2	200-400 mm	- good concrete - maximum nominal aggregate size 25 mm - 35 mm diameter rebar located at 380 mm depth
		1-3	400-640 mm	- good concrete - maximum nominal aggregate size 25 mm
Draft Tube - Cores				
CDTEW1	Draft Tube East Wall	1-1	0-185 mm	- good concrete - maximum nominal aggregate size 35 mm
CDTEW2	Draft Tube East Wall	2-1	0-165 mm	- good concrete - maximum nominal aggregate size 25 mm
CDTEP3	Draft Tube East Bay East Pier	3-1	0-210 mm	- good concrete - maximum nominal aggregate size 25 mm
CDTEP4		4-1	0-200 mm	- good concrete - maximum nominal aggregate size 25 mm
CDTEP5		5-1	0-190 mm	- good concrete - maximum nominal aggregate size 25 mm

All cores 100 mm diameter.

APPENDIX B

R.H. SAUNDERS G.S.
Concrete Movement Investigation
Photographs - Crack Mapping of Concrete Cores

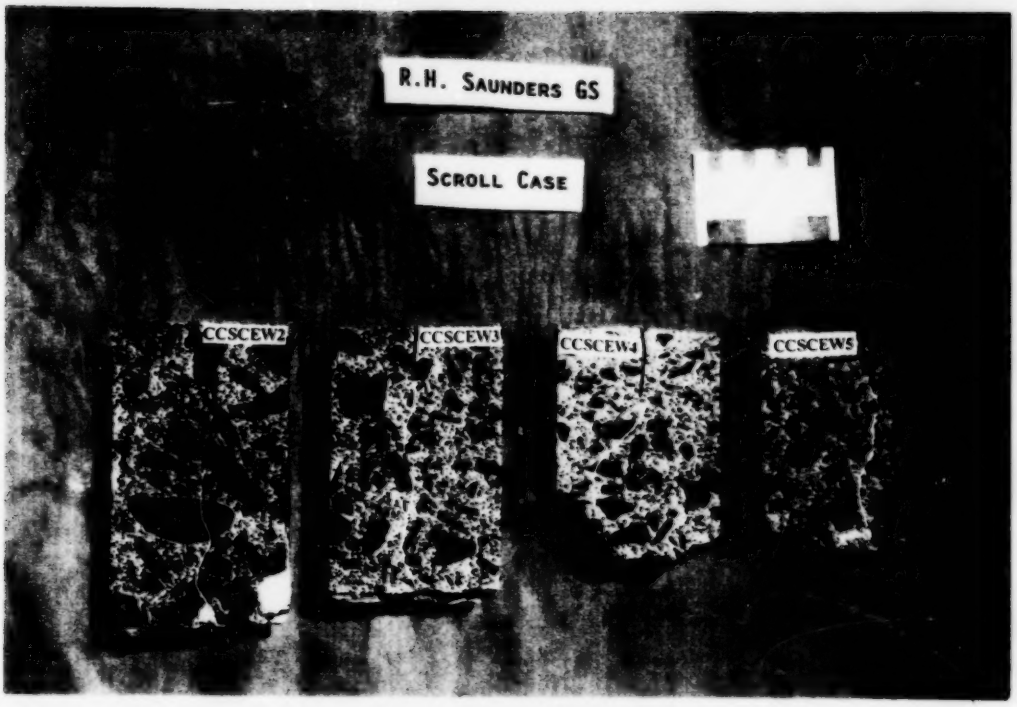


Figure B1
Concrete cores from scroll case
(CCSCEW2, CCSCEW3, CCSCEW4, CCSCEW5)

Figure B2
Concrete cores from intake - scroll case
(CCITEW6, CCITEW7, CCITEW8, CCITEW9)

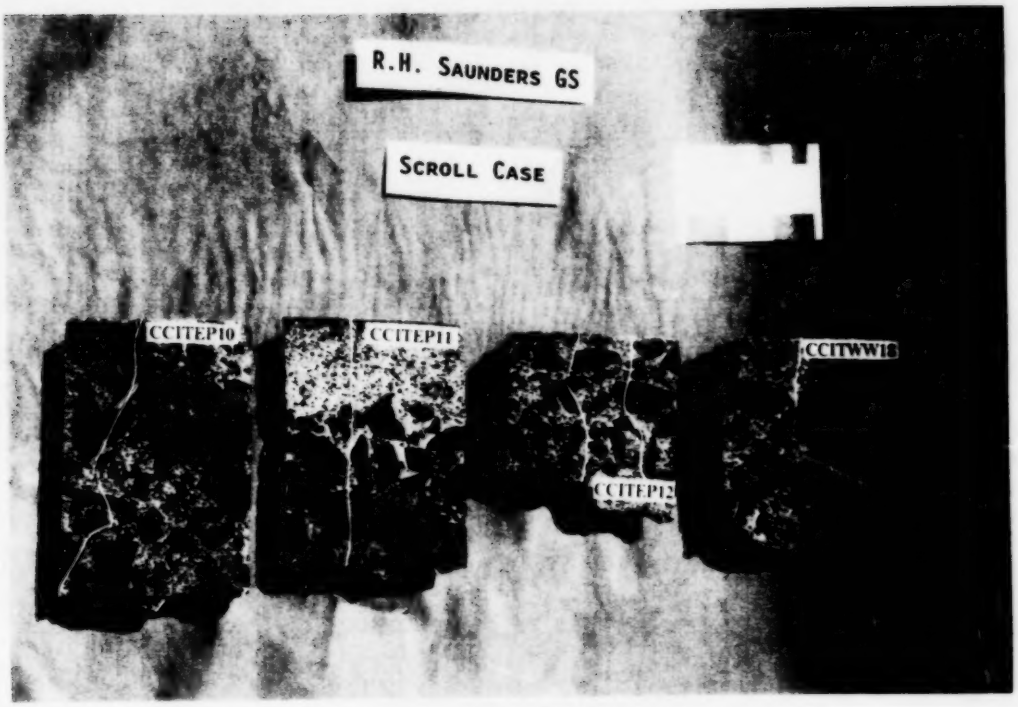


Figure B3
Concrete cores from intake - scroll case
(CCITEP10, CCITEP11, CCITEP12, CCITWW18)

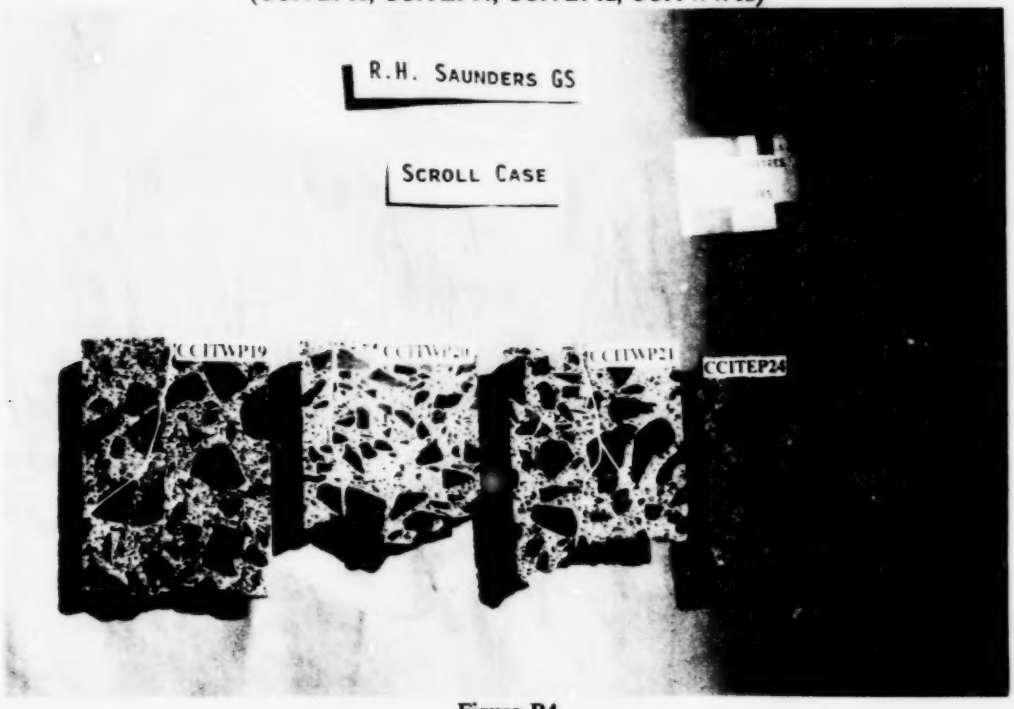


Figure B4
Concrete cores from intake - scroll case
(CCITWP19, CCITWP20, CCITWP21, CCITEP24)

Figure B5
Concrete cores from intake - scroll case
(CCITEP25, CCITEP26, CCITEP27, CCITEW28)

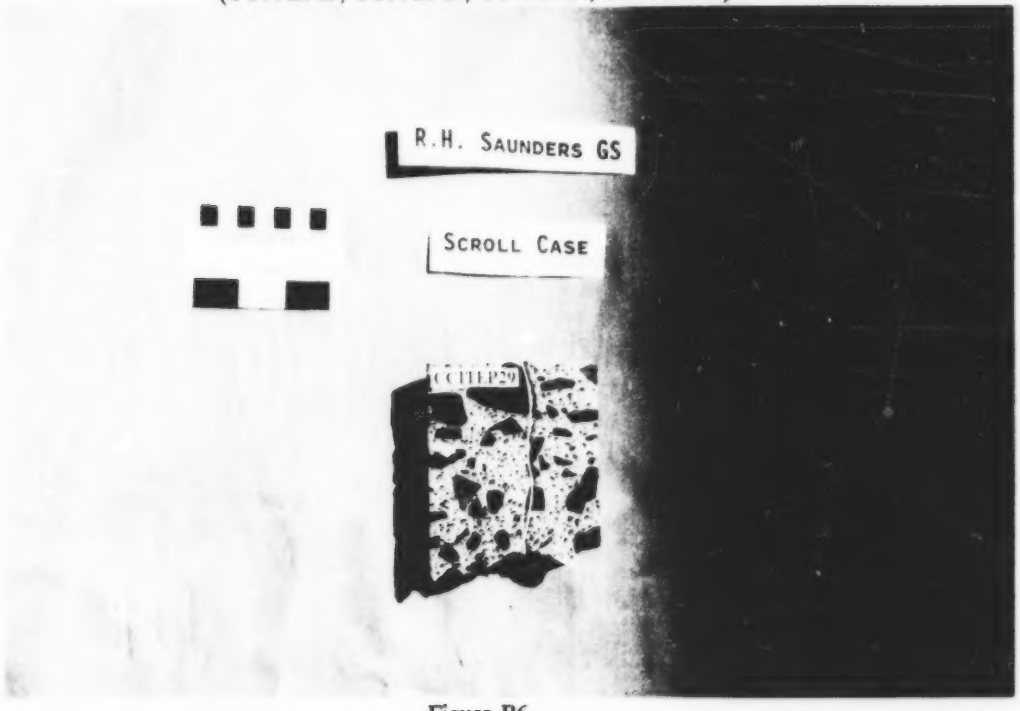


Figure B6
Concrete cores from intake - scroll case
(CCITEP29)

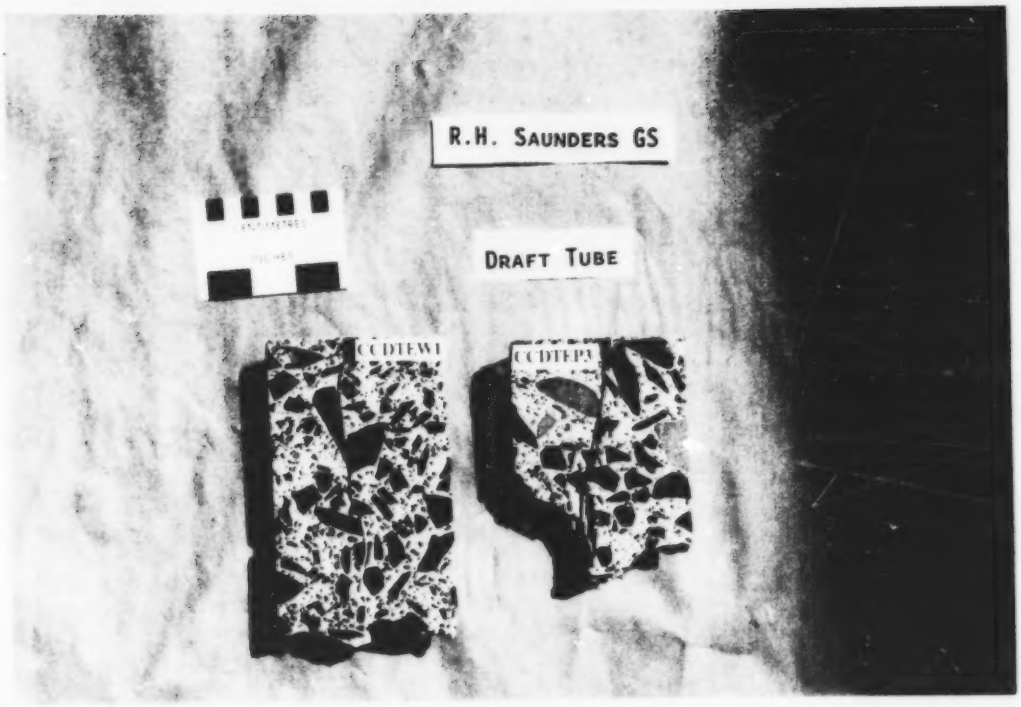


Figure B7
Concrete cores from draft tube
(CCDTEW1, CCDTEP3)

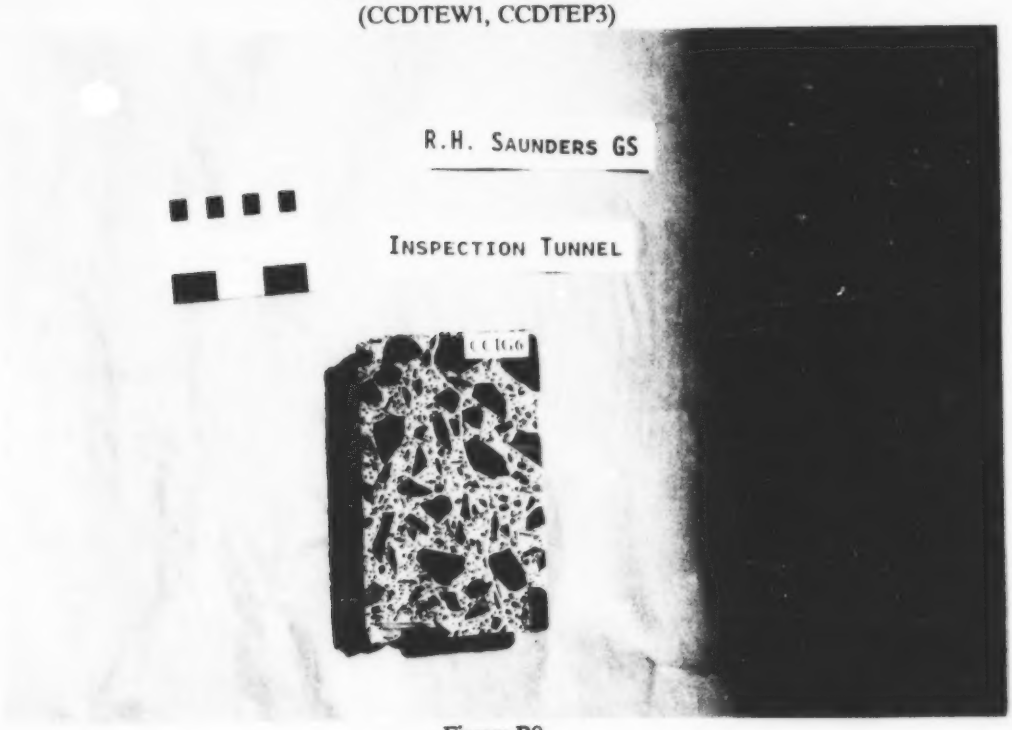


Figure B8
Concrete cores from inspection tunnel
(CCIG6)

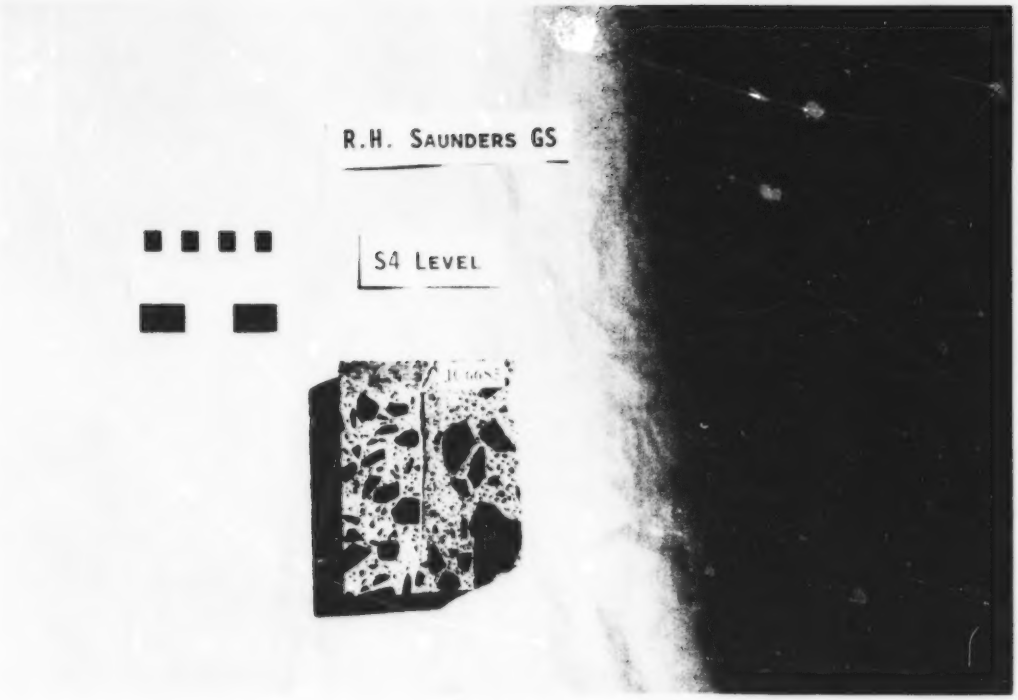


Figure B9
Concrete cores from S4 level
(JC66S5)

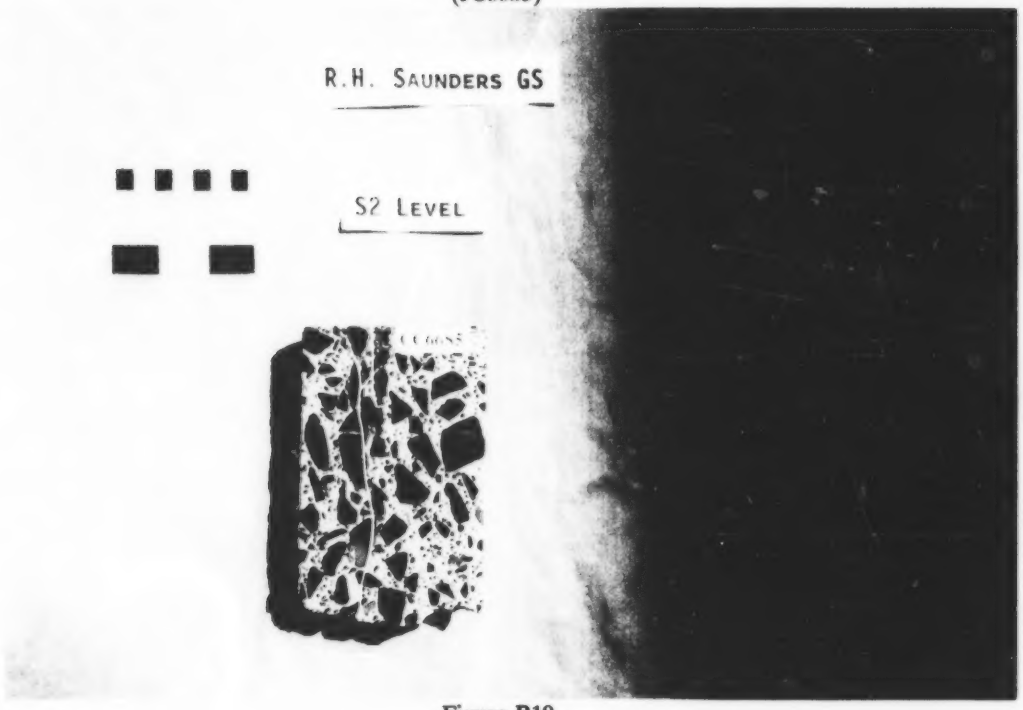


Figure B10
Concrete cores from S2 level
(CC66S5)